ECONOMIC GEOLOGY

WITH WHICH IS INCORPORATED

THE AMERICAN GEOLOGIST

VOL. I SEPTEMBER–OCTOBER, 1906 No. 8

THE SALIENT FEATURES OF THE ECONOMIC GEOLOGY OF NEW ZEALAND.

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INTRODUCTION.

The three principal islands of the British colony of New Zealand, known respectively as the North, South and Stewart Islands, are situated in the South Pacific Ocean, between latitudes 34° and 48°. Considering their relatively small area they

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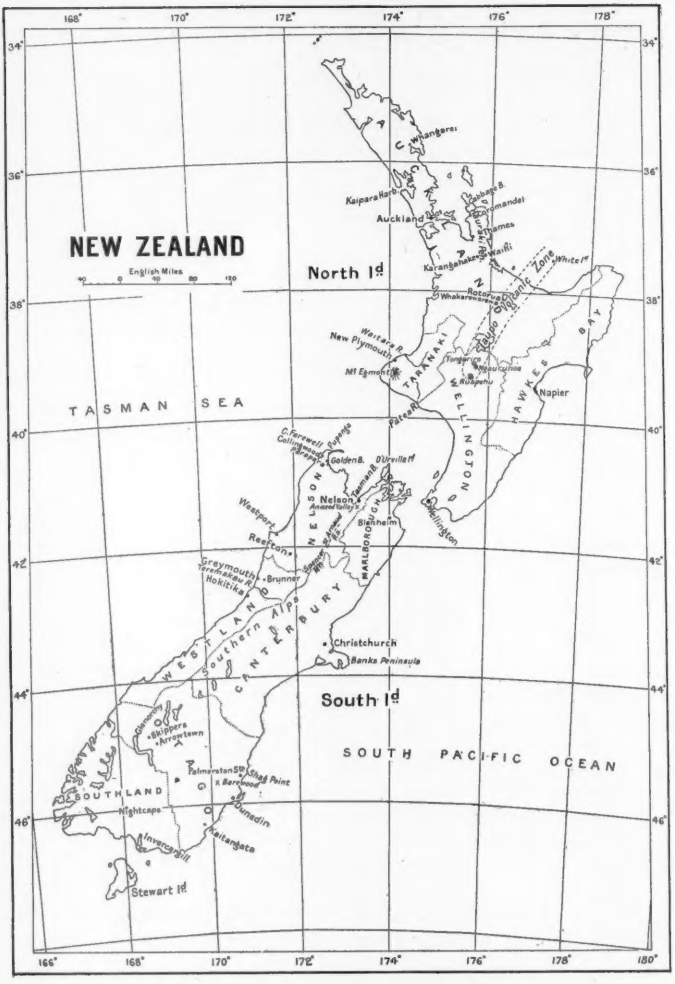

FIG. 52. Sketch map of New Zealand.

present an unusual variety of geological phenomena. In the North Island is a district exhibiting over a large area thermal springs, geysers, fumaroles, solfataras, and other evidences of expiring vulcanism. In the South Island is the snow-clad chain of the Southern Alps, containing extensive snowfields from which flow glaciers, in many cases rivaling and even surpassing in size those of the better known glacial centers of the Swiss Alps and the Caucasus. In addition to these and many other features of chiefly scientific interest, the colony contains mineral wealth widely distributed and of varied mineralogical character. It is the purpose of this paper to give a brief summary of the mineral deposits, their distribution and the broader features of their occurrence without attempting to consider the details of their geological occurrence.

The North Island is divided into the provincial districts of Auckland, Taranaki, Hawkes Bay and Wellington, and the South Island into the provincial districts of Nelson, Marlborough, Canterbury, Westland, Otago and Southland.

DESCRIPTION OF THE CHIEF PHYSIOGRAPHIC FEATURES OF NEW ZEALAND.

Much of the North Island is of broken and rugged topography. It is traversed from northeast to southwest by several parallel ranges of mountains of inconsiderable altitude. There are, however, several areas of flat land, the most extensive being the coastal plain east and south of the splendid volcanic cone of Mt. Egmont near the west coast. At the northeastern edge of this plain are the lofty volcanic cones of Ruapehu, Tongariro, and Ngauruhoe, the latter still faintly active. North of these peaks is the broad volcanic zone of Taupo, exhibiting the varied thermal phenomena already mentioned. At the northern part of the North Island are two peninsulas of broken country—the western and much the more prominent being the North Auckland Peninsula, and the eastern being the Hauraki Peninsula.

By far the greater part of the South Island is mountainous. The central axis is composed of the Southern Alps, with their continuation, the Spencer and St. Arnaud mountains. From

this principal axis radiate subsidiary ranges. In addition there are several high parallel ranges. The Canterbury Plains, which border the coast on the east, form by far the greatest extension of flat land in the South Island, but there are minor stretches of level country at low altitudes in the west, in the north, and in the extreme south of the island.

Stewart Island, much smaller than either the North or South Island, exhibits an area of broken, rugged hills which are in general densely wooded.

RESUMÉ OF NEW ZEALAND STRATIGRAPHY.

The oldest rocks in the North Island are stratified Paleozoic or very early Mesozoic sediments, which compose the main massif of the mountain chains. Overlying these in various localities are Late Mesozoic and Tertiary sediments. Much of the northern and central part of the island is composed of volcanic rocks—both tufa and lava—of Tertiary and Pleistocene age. Apparently the oldest of these volcanics are intermediate in basicity, while the next in age are decidedly acid, and the most recent, basic.

The South Island shows a more complete geological section than the North Island, and a wider petrographical range of igneous rocks. The heart of the Southern Alps, as well as that of some of the parallel ranges, shows in places ancient crystalline schists flanked with Paleozoic and Mesozoic strata belonging to various periods. Much of the rock underlying the Canterbury Plains and the flat land on the west coast of the island, known as the Westland coastal plain, is composed of Tertiary strata, which is also prominent in the southern part of the island and in the north. A considerable portion of the lower country in the South Island is covered by comparatively recent gravels of varied origin—fluviatile, marine, and glacial. Relatively only a small part of the South Island is composed of igneous rocks, though they present a marvellous variety of petrographical forms. Banks Peninsula consists entirely of rocks of this origin, and they are also prominent near the city of Dunedin, in the granite

buttress of the southwestern corner of the island, and in the ridges of the same rocks stretching northward from this buttress parallel with the coast. The so-called mineral belt of the districts of Nelson and Westland is composed in the main of a series of parallel and disjointed sheets of dunite and other magnesian rocks, which have a very small lateral extension, though in longitudinal direction they appear at intervals for nearly two hundred miles.

Stewart Island is composed almost entirely of granites and allied plutonics.

SALIENT FEATURES OF THE ECONOMIC GEOLOGY.

COAL.

Distribution of Coal.—Perhaps in no country of the world is coal more generally distributed than it is in New Zealand, as it occurs in almost every part of the colony—a fact which makes up for the narrowness of the coal seams and the inextensiveness of the basins in which they lie, as compared with coal deposits in other countries. The coal varies considerably in quality, both in regard to the amount of ash and the state of carbonation.

The coals of Kaitangata, Shag Point and Nightcaps, which form fairly wide seams in Tertiary rocks in the southeastern part of the South Island, are lignites of good quality. The seams, which are so widely distributed in the hilly country west of the Canterbury Plains, are all lignites, but not generally so highly carbonized as are the southern coals. The coals of Greymouth and Brunnerton in the Westland District, and of Westport and Puponga in the Nelson District, are bituminous coals of varying degrees of purity. The coals of the North Island, which are chiefly in the northern part, near Auckland and Whangarei, are in general intermediate in state of carbonation between the bituminous coals and lignites. No extensive seams of true anthracite have as yet been found in New Zealand, though there is a very small deposit in early Tertiary sediments at Cabbage Bay in the Hauraki Peninsula, which owes its high percentage of fixed carbon to the metamorphism produced by the extrusion of flows of andesite. Some of the lignite seams of Canterbury also

are said to be in part altered to anthracite, as a product of contact metamorphism.

PETROLEUM.

In many parts of the colony there is abundant evidence of petroleum, though in no locality can it be said to have been proven to exist in great quantity. It has been found and exploited to some slight degree at Kotuku near Greymouth in Westland, near Gisborne in the Auckland District, and more especially at New Plymouth in Taranaki, not far from the base of the lofty cone of Mt. Egmont. In the last mentioned locality the oil seeps out on the surface along the seashore and at a few places in the interior, and gas issues at many points along natural crevices. Boring operations have been conducted in this locality for a number of years, and very recently have apparently met with success. An oil-bearing stratum has been struck at a depth of 2,400 feet, which at present is said by the proprietors to give a steady flow under high pressure. The oil bearing stratum consists of a loosely consolidated marine sand underlying hard argillaceous standstone above which marine sands and clays, more or less hardened, extend to the surface. As far as is known all the beds are disposed in almost horizontal attitude, the lowest being probably of Miocene age, the upper apparently Pliocene.

IRON ORE.

There are in New Zealand two very interesting deposits of iron ore. The most important of these appears at Parapara, in the rugged Cape Farewell peninsula lying west of Golden Bay in the South Island, while the other is visible on the shores of the Tasman Sea, near New Plymouth.

Geologic Character.—The rocks in which the Parapara ore occurs are metamorphic and consist of much corrugated hornblendic and feldspathic schists, sideritic limestones and cherty quartzites. These have been tentatively classified as Silurian by Mr. Herbert Cox, formerly a geologist on the staff of the New Zealand Geological Survey.[1] Unconformably above this series of Paleozoic rocks lies a considerable thickness of coal bearing

[1] Report of the Geological Survey of N. Z.—1882, pp. 44–47.

strata—probably early Tertiary—which consist of limestones, sandstones, grits and coal seams. Forming a mantle over much of the district are thick deposits of glacial gravels and boulder clays. These usually contain more or less gold and have afforded some rich bonanzas in the past where reassorted by stream action.

Structurally the iron ore appears to occur in a broad syncline composed of banded ferruginous cherts and quartzites. In intimate connection with the banded cherts are narrow beds of siderititic crystalline limestone, which is often rusty, due to the oxidation of iron carbonate contained. The ferruginous limestones and banded cherts bear a striking resemblance to similar rocks so closely associated with the iron ore bodies of the Lake Superior region in America. The soft, rusty and much decomposed banded cherts so common in many of the American ranges, may occasionally be observed in the mass of the ore body itself. The width of the actual ore mass visible on the surface averages not less than nine hundred feet, though the iron-bearing horizon is much wider. Broken by several gullies filled with glacial débris, the ore body outcrops in a northwesterly and southwesterly direction for nearly a mile and a half from the Parapara Inlet. Beyond this the iron-bearing horizon is known to extend much farther and is said to contain several deposits of high-grade ore. Mr. George J. Binns, formerly Inspector of Mines for the New Zealand government, estimates that in the large ore body near Parapara Inlet there are not less than 51,835,600 long tons of iron ore in actual outcrop,[1] which could be removed in an open quarry.

The ore is in general a high-grade hydrous hematite, botryoidal, mamillary, and often porous in character. Apparently manganese is a constant constituent. Phosphorus and sulphur are in general low, though there are small quantities of other impurities, principally lime, magnesia, alumina and some silica. In places the ore contains rounded quartz pebbles, often in sufficient abundance to constitute a highly ferruginous quartz conglomerate. This conglomerate is apparently the result of glacial action, which was very effective in the past. It represents

[1] Report of the Geological Survey of N. Z., 1878–79, pp. 59–64.

soft ore, which has been intensely comminuted by the pressure of the ice and mixed with its burden of quartz pebbles to be subsequently recemented into the conglomerate now observable in the outcrops. The conglomeratic portion of the ore is auriferous, the gold apparently being derived from the same source as that in the quartz pebbles. In depth the quartz pebbles are lacking.

Origin.—The origin of this extensive deposit of iron ore is of considerable interest. Briefly stated, the ore has resulted from the concentration of iron oxide by meteoric waters, in the base of a synclinal trough having an impervious basement of schist. The waters had their burden of iron derived either directly or indirectly from the oxidation, partly of iron carbonate, but more especially of the sulphides—pyrite and marcasite.

New Plymouth Deposits.—The deposits of iron ore occurring near New Plymouth, in the North Island, are of a very different character. They consist of magnetic iron sands, all more or less titaniferous, which owe their concentration in thick beds along the sea shore and inland for a mile or more, to the action of the waves or wind. Beds of pure black sand of very fine grain are interstratified with beds of feldspathic quartz sand, containing considerable titaniferous magnetite, and with others practically free from iron. Sometimes the demarcation between the various beds is very abrupt and decided, again much more gradual. Considered longitudinally the beds of pure black sand lense out and are replaced by others in which the iron constituent is lacking or unimportant, and again the latter beds may be replaced by pure black sand. The black sand is supposed to consist of an intimate mixture of magnetite and ilmenite. It occurs very widely distributed, and, there can be no doubt, in very large quantities. It appears at very frequent intervals along the coast on either side of New Plymouth, from the mouth of the Waitara River as far south as the mouth of the Patea.

The black sand has apparently been derived in part from the disintegration of hornblende andesites and more basic volcanics —all rich in titaniferous magnetite, and in part from tufa, representing the comminuted equivalent of these volcanics. Vol-

canics and tufas carrying titaniferous magnetite have a wide distribution near New Plymouth around the volcanic cone of Egmont.

COPPER.

Ores of copper are found in New Zealand at many localities, but there are no known deposits of any considerable size. There has recently been discovered a mineralized horizon, containing native copper, malachite and other ores of copper, near the Kaipara harbor, in the North Auckland peninsula. The country is but little explored, and the exact nature of the deposit has not yet been investigated.

Perhaps the best known deposits of ores of copper are in a heavily mineralized zone stretching from D'Urville Island southward to the Aniseed River, in the neighborhood of the town of Nelson in the South Island. The ore bodies lie in small disconnected and generally parallel lenses disposed along the planes of stratification of the enclosing argillites, and occur close to the contact between the argillites and extensive sills or bosses of dunite. The most common ore is a cupriferous pyrite in which the copper content is generally low. On the surface the oxidation products, malachite, azurite, chrysocolla, cuprite and native copper are occasionally encountered, and in one case (the Champion mine) are important, giving very rich, though small bodies, above the water level. Enriched sulphides are to be seen in some of the lower workings of the United mine above the water level, though the ore is more or less oxidized on the surface.

GOLD.

In the past most of the gold of New Zealand was derived from placer deposits in various parts of the South Island, but more especially in the districts of Westland and Otago. The bonanzas in general occurred where morainic gravels had been reassorted by fluviatile or marine action. The amount of gold derived from this source is now much reduced and the supply of the precious metal in New Zealand is to a greater extent obtained from quartz

reefs.[1] All through the ancient crystalline schists and Paleozoic argillites and grauwackes, which form such an important part of the strata of the South Island, quartz veins are common. Generally these are disposed parallel to the stratification, but are sometimes in fissures transverse to the bedding planes. Although quartz veins of this class are almost innumerable, many of them contain gold only in traces, and comparatively few yield it in payable quantities. The veins are in rocks which exhibit physiographically mature and submature forms, and in consequence are in general merely the remnant of former veins; the upper and probably richer part having been removed in the extensive and varied denudation—sub-aerial and glacial—which the country has undergone.

At present much the most important center of quartz mining in the South Island is at Reefton, where a number of mines are now working—the Globe, the Progress, the Wealth of Nations, the Keep-it-Dark, etc. The ore filling the veins consists chiefly of quartz. This contains a great deal of pyrites, rarely chalcopyrite and arsenopyrite, and often stibnite. In all of the mines the values are very irregularly distributed in the quartz gangue, even near the surface, where the yield is usually higher than from the lower levels. Often not only may the ore-shoots terminate within the quartz mass in the direction both of the strike and dip of the vein, but the quartz gangue frequently itself lenses out and is replaced by comminuted gouge, to reappear either barren or with shoots of rich ore in the continuation of the line of reef. This occurrence of the quartz in patches is one of the most characteristic features of the veins at Reefton. The highest values are almost always along slaty selvages, which are frequently rusty, and where the quartz is of the character known as "magpie stone" by the miners. "Magpie stone" is simply quartz enclosing numerous small angular fragments of argillite or grauwacke, which are the prevailing country rocks of the district.

[1] During the year ending December 31, 1904, the gold export from New Zealand was valued at £1,987,501. Of this amount approximately 48 per cent. was the product of dredging, hydraulic sluicing, etc. In 1905 this percentage was much reduced.

There is a small reefing area near the head of the Wilberforce and Arahura rivers, known as the Westland Reefs district, in which a number of promising auriferous quartz veins have recently been discovered, but which has been as yet very little prospected. Quartz mining is carried on at Taitapu in the Cape Farewell peninsula, in reefs very much like those at Reefton. Quartz veins are also being worked at Skippers, Arrowtown, Barewood and various other places in Central Otago, though none is of important proportions.

The occurrence of the mineral scheelite in many of the quartz veins in Otago is interesting. The quartz with which it is associated is nearly always somewhat auriferous and in places payably so. The scheelite sometimes appears in a decided band running through the quartz, or again intimately intermixed, with the appearance of a pegmatite. At Barewood, Glenorchy, and Macrae's, near Palmerston South, the mineral is found in sufficient quantity to pay for working.

Much more prominent than any of the centers of quartz mining in the South Island and of widely different character are the goldfields of the Hauraki Peninsula of the North Island, which contain the mining centers of Coromandel, Thames, Karangahake and Waihi, in addition to many less prominent mining localities. The output of gold from Coromandel is now comparatively small. At Thames the Waiotahi mine is at present yielding bullion to the value of £18,000 to £20,000 per month, but there is no other mine of importance. The site of the Waihi mine, one of the greatest gold mines of the world, is a center of immense economic importance as well as of scientific interest. At Karangahake is situated the Talisman mine, which is now the third gold producer in the colony.

The oldest rocks of the Hauraki goldfield apparently consist of unfossiliferous argillites and grauwackes, which are probably very late Paleozoic or early Mesozoic. Unconformably above these are late Cretaceous rocks containing unimportant coal seams, which occur as widely separated, isolated remnants in the northern part of the Hauraki Peninsula. On the denuded surface of these sedimentaries have been disposed thick and widely

distributed volcanic deposits, flows, breccias and tuffs of andesitic character, above which are others of rhyolitic character. By far the most important veins of the Hauraki Peninsula are in the andesitic flows or in the fine-grained andesitic tuffs. Veins occurring in the coarse andesitic agglomerates and tuffs rarely carry much gold, while those appearing in the rhyolites are decidedly unimportant as compared with those in the andesites. A few relatively unimportant veins are found in the older sedimentary rocks. The andesites are often tremendously altered, especially near the veins. In fact the rock in places has been changed to a mass of chlorite, epidote, sericite, calcite, quartz and pyrite, giving the so-called propylite. There were evidently at least two periods of vein deposition, much the more important apparently being the result of the andesite extrusion, while the second period of vein formation succeeded the outpouring of the rhyolites. Sinter deposits widely distributed throughout the Hauraki Peninsula testify to the enormous extent of hydrothermal activity in the past, and a few scattered hot springs show that it has not yet ceased. The veins are apparently mainly deposits by hot siliceous solutions, carrying a great deal of hydrogen-sulphide in preëxisting fissures, greatly enlarged by replacement of the wall rock.

Of the payable veins of the Hauraki goldfields there are two more or less distinct types: those which occur in decided and definite veins, in which the payable ore is contained chiefly in a well-demarcated ore shoot with considerable horizontal continuation and with longitudinal extension from level to level, and those in which not only is the quartz of very irregular width, but the values are almost entirely in small disjointed patches, often of the enormous richness of "jewelery shop" ores. Of the former class much the most conspicuous example is given by the more or less connected reefs worked in the Waihi mine at Waihi, though the Union, Amaranth and Silverton veins at the same place, and the Talisman vein at Karangahake are of the same class. Of the "jewelery shop" class of veins, the reef systems of the Hauraki, Kapanga, Royal Oak and Tokatea mines at Coromandel, and the reef systems of the Kurunui, Caledonian, Moana-

taiari and Waiotahi mines at Thames are good examples. Of these the only one now giving heavy returns is the Waiotahi. A bonanza of great richness was discovered recently in connection with this mine, which has in consequence given a heavy output for the past year.[1] The bonanzas of free gold in the veins of the Waiotahi type are apparently always at points where the vein is heavily mineralized with pyrite, with which is sometimes associated sphalerite, stibnite, and chalcopyrite, and occasionally native arsenic. The bonanzas frequently have an intimate connection with the faulting of the vein. The faults, formed subsequent to the original period of vein deposition, may have determined the position of the bonanzas formed during a period of secondary enrichment of the vein, either by acting as barriers to migrating auriferous solutions, or by forming channels along which solutions came, reacting with those in the original vein channel.

The great Waihi mine, which is now working on the complex system of branching reefs—the Martha, Welcome, Empire, Royal and several smaller veins—had an output during the year ended December 31, 1905, of £712,066 sterling. This year its output will be even greater. The four weeks ending June 16, 1906, gave the record return of £62,470 sterling. Those reefs of the Waihi mine system, which approach the surface, show an oxidized capping of moderate though not of bonanza richness, which gradually is replaced in depth by sulphide ores. The gold is very rarely visible to the unaided eye, though a considerable portion exists as free gold. One of the most characteristic features of the reefs of the Waihi mine system is the continuity of the "pay ore," both in horizontal and vertical extension. If there was any enrichment of these veins subsequent to the original deposition of the quartz, which seems very likely, it was probably by secondary solutions ascending along the reef channels, excepting near the surface, where descending solutions gave a limited concentration. Some of the veins of the Waihi reef system are of immense size—the Martha reaches a width of

[1] For the year ended June 30, 1906, the output was approximately £160,000 sterling.

sixty feet on the surface, and at the levels at present being opened at about eight hundred feet beneath the surface, it is, where widest, over twice that width. It is interesting to note that in general the veins of the Hauraki Peninsula show a diminution in the amount of gold in the electrum in passing from the northern to the southern portion of the field.[1]

Very interesting evidence on the origin of gold and silver in quartz veins is given by certain hot springs in the center of existing hydrothermal activity in New Zealand—the Taupo volcanic zone. Sinter taken by the writer from the rim of a very ebullient spring at the Maori settlement of Whakarewarewa, was found to contain on analysis, silver to the amount of 4 ozs. 0 dwts. 18 grs. per ton, and gold to the amount of 1 dwt. 4 grs. per ton.[2] The sinter analyzed was stained with sulphur, but showed no visible evidence of any sulphides. Analysis made from the sinter deposited in a wooden trough used to conduct water from the same spring at Whakarewarewa, gave the following result in the precious metals:

Gold	0 dwts.	12 grs.	per ton.
Silver	15 "	3 "	" "

The great geyser of Waimangu, which broke into action some years after the terrible Tarawera eruption of 1866 and remained active until November, 1904, deposited a blackish material, consisting chiefly of sulphides, but containing neither gold nor silver. Some mud obtained by Dr. Wohlmann, the government balneologist, from a hot spring in the sanatorium grounds at Rotorua, gave the following somewhat remarkable analysis:

Silica	69.30
Alumina	4.52

[1] For further particulars about the Waihi mine see the following papers: (1) "Notes on the Geology, Quartz Reefs, and Minerals of the Waihi Goldfield," by P. G. Morgan, in the *Transactions of the Australasian Institute of Mining Engineers,* Vol. VIII., Part II. (2) "The Hauraki Goldfields, New Zealand," by Waldemar Lindgren, in the *Engineering and Mining Journal of New York,* February 2, 1905. (3) "The Hauraki Goldfields," by P. G. Morgan, in the same journal, circa, May 4, 1905.

[2] All analyses given in this paper are by Dr. J. S. Maclaurin, *Colonial Analyst.*

Iron oxides	2.00
Titanium oxide	0.58
Lime	1.00
Magnesia	0.10
Soda and potash	1.30
Sulphur combined	1.40
Sulphur free	6.09
Organic matter	10.01
Water	3.70
	100.00

Microscopic examination of the deposit showed that it consisted mainly of quartz and amorphous silica with a little feldspar. The mud also contained 5 grs. of gold and 6 dwts. 1 grain of silver per ton. It is evidently not a deposit from the spring, but is merely a siliceous tufa impregnated by the thermal solutions.

PLATINUM.

Platinum has been found at many points in the South Island, in the alluvial drifts, but never in sufficient quantities to be of any economic value, excepting where saved with gold. Platinum has been reported from the Queen of Beauty quartz reef at Thames, and also from an occurrence of massive pyrites at Coromandel. During the past season a number of platiniferous quartz veins were discovered by the writer near the Teremakau River in the district of Westland in the South Island, in close proximity to sheets of altered magnesian eruptives—apparently originally dunite and situated parallel to the stratification of the enclosing phyllites. The quartz is somewhat vitreous, and in general very "hungry" in appearance. Iron pyrite is fairly common, and iron oxides derived from its alteration. In three analyses made of the platiniferous quartz, the platinum was found to occur associated with silver and always in the approximate ratio of seven parts of silver to one of platinum. The following is a characteristic result, showing the amount of platinum and silver:

Platinum	0 ozs.	3 dwts.	8 grs.	per ton.
Silver	1 oz.	4 dwts.	9 grs.	per ton.

It seems possible that the platinum and silver may exist in some mineralogical combination, though no data were obtained to substantiate this hypothesis.

An interesting product of metamorphism of the magnesian eruptives, near which the platinum veins just described occur, is the mineral nephrite—the much valued Pounamu and Tangiwai of the Maoris and the precious "greenstone" of commerce. This mineral, which is apparently a massive actinolite or allied amphibole, occurs as segregations from a few inches to several feet in width in a talcose matrix—also a product of alteration of the magnesian eruptives. Many analyses made of the magnesian eruptives failed to show any platinum actually existing in them.

TIN.

Cassiterite has been found in the form of "stream tin" in some of the streams amid the rugged hills of Stewart Island, and has been reported to occur actually "in situ" in granite.

Ores of antimony, lead, zinc, and several other metals have been discovered in New Zealand, but scarcely in sufficient quantity to deserve especial mention in this paper.

Much of the wild, mountainous country of the South Island and of the thickly wooded central and northern parts of the North Island are still unexplored, and vast mineral wealth may yet be discovered in these areas of "terra incognita."

THE MICROSCOPIC EXAMINATION OF OPAQUE MINERALS.

WILLIAM CAMPBELL.

INTRODUCTION.

In the year 1863 Dr. Sorby, after examining rock sections under the microscope by transmitted light, took up the study of meteorites[1] and of artificial irons.[2] Fifteen years later Martens' paper on the microscopical examination of iron[3] appeared and was followed after an interval of several years by papers from Bayles,[4] Dolliak,[5] Garrison,[6] Osmond and Werth[7] and Wedding.[8] From this beginning the microscopic examination of metals and alloys has made rapid advancement and is now a well-known method of research under the title of "metallography."

For the past two or three years the methods used in metallography have been applied to opaque minerals and the results obtained have been so successful that it seems fitting to set forth certain details in the hope that they may prove of value to others interested in the subject. This is especially true inasmuch as investigations of this kind will serve to render intelligible many of the relations between the minerals of ore deposits which have heretofore been obscure.

The microscopic examination of polished surfaces of opaque minerals falls under two heads. The first is the examination of single minerals to determine their microstructure, inclusions of other substances, method of decomposition, etc., and is especially

[1] *Proc. Royal Society,* XIII., 333; British Association Report, 1865, I., 139.
[2] British Association Report, 1864, II., 189, see also *Journal Iron and Steel Institute,* 1886, 140; 1887, I., 255.
[3] *Zeits. des Ver. Deuts. Eng.,* XXI., 11, 205, 481; XXIV., 397.
[4] *T. A. I. M. E.,* XI., 261.
[5] Mittheil. über Gegenstände des Artillerie und Geniewesens, 1883, 9, p. 467.
[6] *T. A. I. M. E.,* XIV., 64.
[7] *Comptes rendus de l'Acad. des Sciences,* Vol. C., p. 450.
[8] *Journal Iron and Steel Institute,* 1885, 87.

useful in determining whether certain minerals of more or less complex formulæ owe this complexity to a mechanical mixture or not. The second heading embraces the examination of ore bodies and determines the relative ages of the various constituents and of any changes, mechanical or chemical, which have taken place. Thus with opaque minerals we obtain the same results as are obtained in petrology by means of thin sections of transparent minerals.

PREPARATION OF SPECIMENS.

It is of great importance to start with a specimen of convenient size which can vary within certain limits, depending on the type of microscope used. A specimen one and one-half inches in diameter and one-half inch thick is of the dimensions most suitable for the work, and if the sample to be examined cannot be reduced to this size, it is better to make two specimens of it, because two small specimens are more readily polished than one large one.

In dealing with a hard, brittle substance, as a rule, it is easy to break off a chip about one-half inch thick and dress it down to about one and one-half inches in diameter. For a soft, less brittle substance a small hacksaw can often be used, as in the case of the native metals. When the material to be examined is very brittle and tends to fall to pieces during polishing, it is necessary to supply a firm background for support. For this purpose we can use certain waxes and cements, but they must be of such a nature that they do not soften under the influence of the slight heat produced in polishing.

It must be remembered that we can strain minerals and native metals just as we strain metals and alloys; and where this strain has been severe the final structure will be more or less modified. In the examination of native copper, silver, bismuth, etc., there are usually found in the finished specimen, no matter how carefully it be polished, numerous slip-lines, slip-bands, or what appears to be multiple twinning. This results from the more or less severe straining which these metals undergo in the process of mining.

In the case of the harder minerals, however, the strains produced in mining leave little effect except in the near vicinity of the cause which has produced the strain, and the occurrence of slip-bands and slip-lines usually denotes great strains and movements in the ore body itself. This may be frequently observed in specimens of galena, magnetite, chalcopyrite, pyrrhotite, etc.

When the original specimen is too small to handle with ease, a block or base must be made. Fusible metal is often convenient, or a hole can be drilled in a piece of steel and the specimen firmly imbedded therein; the steel and specimen are then polished as a whole.

GRINDING AND POLISHING.

In grinding and polishing the main object is to produce a perfectly flat surface with a good polish, as free from scratches as possible. When a lap-wheel is at hand, a flat surface can be made by grinding as in the process of making rock-sections. The specimen is then rubbed on a ground-glass plate covered with well moistened emery-powder (No. 100), and the rubbing is continued until all of the deep pits have been worked out. Carborundum powder seems to give quicker results than emery in many cases.

Where a lap-wheel cannot be had, an emery-wheel or even a grindstone may be substituted. In fact, in the case of native metals these are preferable and are followed by a dead-smooth file.

For very hard substances like pyrite it is best to continue the treatment on the glass plate, using Carborundum powders, No. 3 F. and 4 min. For softer substances, like galena, chalcocite, etc., it is best to take the specimen down on No. 00 emery paper which has previously been rubbed with a piece of hard steel to remove the coarsest particles. Where the material is very soft, care must be taken not to distort or strain the surface during the process of grinding. In many cases this can only be overcome by finishing on a very fine-grained water-of-Ayr stone with water. Whichever method is used, the final result ought to be a flat surface, free from pits and containing nothing but fine scratches, such as can be taken out in the next stage of the process.

This consists in rubbing the specimen on French emery papers (Hubert) Nos. 0, 00, 000, and 0000. These may be procured in sheets 13⅜ inches × 9 inches, and can be cut up into three long or four cross strips and mounted on flat, smooth boards 4 × 14″ or 4 × 10″ with thumb-tacks. Starting with paper No. 0, the specimen is rubbed backwards and forwards in one direction until all the scratches due to the previous treatment have disappeared, when it is ready for the next board. On passing from one paper to another the specimen is turned through an angle of 90°, so that the new scratches are at 90° to those made by the previous paper. Rubbing is continued until all the scratches of the previous paper have been obliterated. It is of great importance to keep all polishing boards free from grit. This is difficult at first, but with a little practice the sound produced in grinding renders the presence of any foreign substance readily perceptible.

The final polish is obtained by rubbing the specimen on a piece of ribless broadcloth or baize stretched tight on a hardwood block and covered with water and well-washed rouge. Some may prefer to use blocks with diamontine powder or tripoli between the last emery-paper and the rouge, but in most cases they are not needed.

It is always necessary to wash the rouge, tripoli or diamontine powder free from all grit or coarse particles. For rough work the rouge can be shaken up in a large bottle (90 oz.) using one volume of rouge to about ten of water, till thoroughly mixed. After allowing to stand for a few minutes, a siphon with a hook at the end is introduced and the liquid all run off but the last two inches, which contain all the coarsest particles. By repetition we can produce rouge of any fineness we desire, which for convenience can be kept in an ordinary wash-bottle.

For the very finest work it is often necessary to classify the polishing (and emery) powders, which can be done by a method similar to that used by Schloesing for the analysis of kaolins.[1] The formation of lumps of coarse and fine particles in the process

[1] Le Chatelier, *Metallographist*, 1901.

of levigation is due to the presence of carbonate of lime in tap-water. Schloesing therefore washes the powders to be classified with water containing 0.1 per cent. nitric acid, which dissolves the carbonate of lime derived either from the water or from the powder treated. After the mixture has settled, the clear water is run off and replaced by distilled water. After stirring well and once more settling this is repeated until all the acid has been removed. To help the suspension of the finest particles a little ammonia is now added. The liquid is drawn off at the following intervals: fifteen minutes, leaving all the coarse grains unsuitable for polishing; one hour, a powder for the first step in the polishing; four hours, a powder for polishing material like iron; and so forth. The addition of a little acetic acid precipitates the last deposit in a few hours. The powders are best mixed with soap in the form of a paste.

Rouge from calcining iron oxalate, alumina from calcining ammoniacal alum, chromium oxide from the combustion of ammonium bichromate and commercial flour-emery can all be used after such a classification. The Carborundum Co. supply classified powders.

A motor-driven polishing wheel greatly reduces the labor of polishing, but requires more care than the hand method. Stead has designed an excellent little machine[1] for this purpose. Sauveur's machine,[2] consisting of four discs revolving in a vertical plane, is designed for metallographic purposes, but can be used for minerals as well. The outer disc is an emery-wheel whilst at its back is a disc covered by canvas and armed with fine emery-powder. The second pair are usually covered with broadcloth and saturated with moist tripoli and rouge respectively. It is a simple matter to set up a vertical spindle with a cast-iron plate six to eight inches in diameter, upon which broadcloth or baize can be stretched. To keep the wheel free from dust, it is best to cover it with a box having a glass top and a hole at the side for the arm.

[1] "Notes on Metallography," *School of Mines Quarterly*, 3, XXV.; "Practical Metallography," *Cleveland Inst. Engineers*, February 26, 1900.

[2] *Metallographist*, IV., 1901, 275.

Whether we polish by hand or wheel, the specimen is finished when the scratches from the last emery-paper disappear, as it is usually a waste of time to try and work out any deeper ones. During polishing it is necessary to keep the specimen turning round continually, otherwise pits are liable to form, due to uneven polishing. When the polishing is complete, the specimen is washed free from rouge, and carefully dried, which is best done by rubbing on a small block ($4'' \times 2''$) covered with very fine chamois skin, or else by immersing in alcohol and mopping (not rubbing) with a fine clean rag.

In practice the process of polishing, grinding, etc., can be made much shorter than the above description indicates, but in this no general rule can be given for the personal equation has to be considered, as well as the material on which the work is performed.

DEVELOPMENT OF STRUCTURE.

Having obtained a more or less perfectly polished surface, the specimen is mounted and examined. As a rule, we can distinguish the different constituents by their color, habit, hardness, etc. It may, however, be necessary to apply further treatment to develop the structure or distinguish between two or more constituents. This usually takes the form of etching with various reagents and in the preliminary work can be followed with a strong lens or even under the microscope.

Using 1.42 nitric acid, solutions of 1 acid: 2 water and 2 acid: 1 water prove useful in developing the structure of certain copper minerals like chalcocite, bornite, etc. Similar strengths of hydrochloric acid can be made up, and the solutions can be used both hot and cold. In the event of the above proving unsatisfactory, solutions of potassium cyanide, the chlorides of copper, tin or iron, sodium thiosulphate, the alkaline sulphides, etc., can be tried. Lastly, the use of the electric current in etching may be mentioned because of the ease of regulation.

After etching, the specimen is thoroughly washed under the tap, is immersed in alcohol and dried by pressing with a soft, clean rag. The specimen must not be rubbed in drying, and if

any deposit is formed during etching it can usually be removed by gently rubbing with the tip of the finger whilst under the tap. It may happen that the deposit formed veils the structure. If it cannot be dissolved by some other reagent a method of polish-attack can be tried. This consists in adding some of the etching solution to a polishing board and rubbing with just enough pressure to remove any deposit as formed.

MOUNTING.

When the top and bottom of the specimen are parallel it may be fixed on a glass slide by Canada balsam. This, however, is the exception. For temporary mounts, several methods give satisfaction. Sauveur makes a small brass mount in which the specimen is held in place (with the polished surface in a plane parallel to the stage of the microscope) by an elastic band (see Fig. 57). For small specimens of steel Stead cements a short length of brass tube to a piece of glass. The tube is nearly filled with sand and placed on the stage. The specimen is placed face upwards on the sand and is pressed down by a glass slide until the latter rests on the brass tube.

The most convenient mountant is modelling wax. To obtain a perfectly level surface, the specimen is laid face down on a clean sheet of glass, a short brass cylinder is placed over it—the cylinder being turned down true and of such a height that the specimen does not project above it. Some wax is stuck on a glass slide, which is pressed down on the section until it rests on the brass ring. These rings can be turned down on a lathe from two-inch tubing—five are usually enough, viz., one-fourth, one-half, three-fourths, one, and one and one-fourth inches high. Instead of brass rings, two equal piles of glass slides can be used, the specimen being laid between them.

If a permanent mount is required, a wax composed of resin, beeswax, red ochre and plaster of Paris is very satisfactory. It remains plastic, when warmed, quite long enough for levelling and then sets firm and hard.

Many specimens tarnish, but by covering them with a film of zapon they are preserved and can still be examined even under

high powers. If a cover-glass with Canada balsam is used, the reflected light from the surface of the glass blurs the image with low powers and vertical illumination.

MICROSCOPE AND ACCESSORIES.

The ordinary form of petrographical microscope with a fair working distance between the objective and stage is all that is required. Any good type of microscope, however, can be used. A firm, solid stand gives rigidity, especially for high-power work, and while a revolving stage is an advantage for oblique illumination, it is not essential.

In this work the illumination must come from above and therefore reflectors must be used. With objectives of one inch and more, the Sorby-Beck reflector is used and by it we obtain oblique and vertical illumination. It slides over the objective by means of a collar and consists of the parabolic reflector of Beck and of Sorby's reflector, a small mirror set at 45° to the axis of the microscope and attached so that it can be turned out of use by means of a milled head.

For oblique illumination the Sorby mirror is turned out of the field and leaves the Beck parabolic reflector in use. Its working is shown diagrammatically in Fig. 53, where the horizontal rays of light *L* strike the parabolic reflector *B*, are thrown down onto the specimen *Q* at all angles but the vertical, and hence if the specimen be perfectly smooth it will appear quite dark, for no light will be reflected into the objective *O*. Oblique illumination is used to show up the structures of surfaces after etching or polishing in relief.

For vertical illumination, the Sorby mirror is turned back into the axis of the microscope and is so fixed that it rests in position when it covers one-half of the lower lens of the objective. In Fig. 54 the horizontal rays of light *L* strike the mirror *S* set at 45°, and are reflected vertically downwards onto the object *Q*, and are again reflected vertically upwards into the objective *O* towards the eye-piece at *E*. Hence a perfectly flat specimen will appear bright whilst a broken up structure will produce more or less shade.

For higher powers than one inch the Beck illuminator gives very excellent results. It fits between the objective and the nose of the microscope. It consists of a short brass tube in which is fixed on a pivot a small, thin disc of glass which can be set at any angle by means of a milled head, shown in Fig. 57. The glass disc is adjusted to 45° with the axis of the microscope. The beam of light *L*, Fig. 55, enters through the circular hole in the side of the reflector, strikes the disc *G* at 45°, is reflected vertically downwards through the objective *O* onto the specimen *Q* and back again towards the eye-piece at *E*. As in the case of the Sorby mirror, all flat parts of the specimen appear bright,

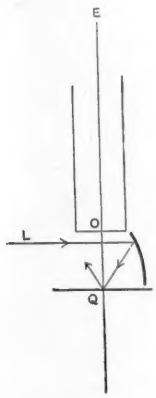

FIG. 53.

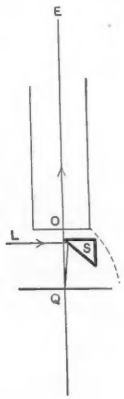

FIG. 54.

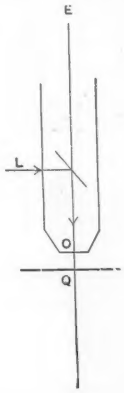

FIG. 55.

whilst rough ones have more or less shade. In other words, we have vertical illumination.

The Zeiss prism can also be used for vertical illumination and is shown in Fig. 56. The beam of light *p* enters through the opening in the side of the reflector *R* (which, like the Beck, is screwed between the nose of the microscope and the objective) and is reflected down by the prism through the objective onto the specimen as before. Nachet also makes this form of reflector.

With reflected light the multiple nose-piece does not work well

because the reflectors are in the way. The Zeiss object glass changer is very convenient, however, for quick work.

Several microscopes have been designed solely for metallographic work. That of the Boston Testing Laboratories, manufactured by Bausch and Lomb, is shown in Fig. 57. The main advantage possessed by this microscope is the raising and lowering of the stage by rack and pinion motion. Having once adjusted the illuminating apparatus, lamp, condensers, etc., so that the beam of light is centered on the aperture of the vertical illuminator, their position need not be altered, for all adjustments

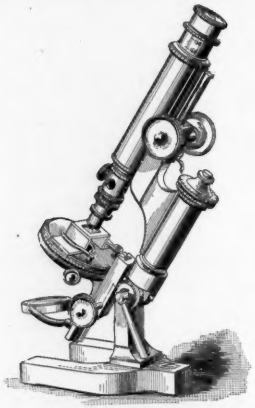

FIG. 56. Zeiss prism for obtaining vertical illumination of opaque minerals.
FIG. 57. Bausch and Lomb metallographic microscope.

for change of specimens or objectives are made by the motion of the stage. The microscope is usually used in the vertical position.

The Martens' stand, shown in Fig. 58, manufactured by Zeiss, is made to use in the horizontal position. Although the tube is provided with a coarse adjustment T' by rack and pinion, this is only used for transmitted light or for adjusting the tube to the illumination. Focusing is performed by moving the stage by rack and pinion T'' and the fine adjustment M. The stage can be clamped in any position by the arm H. When the camera

is used, the fine adjustment is worked by the rod *St* through the joint *Tr* and the thread on *S* which engages in the teeth on the circumference of the head *M*. The mirrors *Sp* are attached to the bar *Sl* for low powers, whilst for high power work the Zeiss prism is used. As before the optical bench attachments are set up and adjusted once for all and all subsequent movement takes place in the stage and not in the tube of the microscope.

By using a microscope in the horizontal position a much longer camera can be used than when working in the vertical.

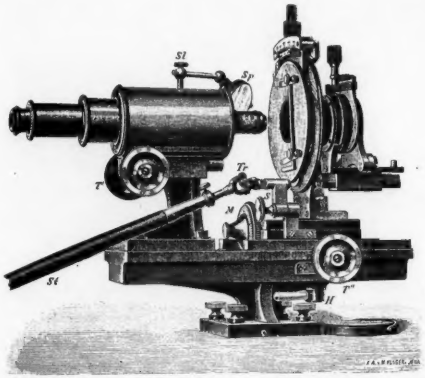

FIG. 58. Martens' Stand.

The Le Chatelier microscope[1], manufactured by Pellin, Paris, consists of a horizontal eye-piece tube fitted to a firm tripod support, in the body of which are fixed prisms so that the objective points upwards. Fig. 59 is a diagrammatic sketch of a vertical section of the older form. The specimen to be examined, *O*, rests on a support or stage *S* which stands on a screw-collar whose fine adjustment gives sharp focusing. The face of the specimen points downwards to the objective *A*, and hence the specimen can be of any shape provided it has one polished surface. The size of the specimen can also vary within wide limits. The illuminating beam of light *L*, passing through the tube of

[1] *Revue Générale des Sciences*, January 30, 1897.

the microscope, strikes the illuminating prism P, is reflected through the objective A upon the specimen O, and then passes back through the objective A to the prism P', which totally deflects it along the eye-piece tube to the eye-piece at L'. The face of the illuminating prism P is really composed of two planes, one of them making an angle of $22\frac{1}{2}°$ with the horizontal, the other a similar angle with the vertical, thus deflecting the horizontal beam of light L into the vertical. To photograph a specimen, a short camera is screwed on the body of the microscope directly below the objective and prisms. For direct observation

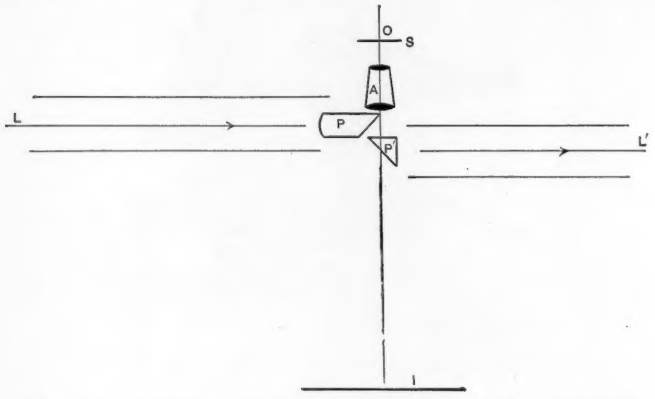

FIG. 59. Diagrammatic vertical section of older form of Le Chatelier microscope.

the reflecting prism P' covers the objective, but for photography it is drawn out of action and the image is thrown upon the photographic plate at I.

In its latest form this microscope has been fitted with a rack and pinion adjustment for focusing, which is shown in Fig. 60. The stage has three motions by the screws a, b and c. For focusing, the coarse adjustment is worked by B and the fine by R, fitted with the flexible rod S for use in photographing. The tripod is fitted with levelling screws. The lower prism is now

fixed on a pivot and the eye-piece tube lies at 90° to the illuminating tube, whilst the camera has the old position of the eye-piece and can be represented by L' in Fig. 59. Thus after examining the specimen through the eye-piece the lower prism is turned through 90° and light is reflected into the camera, L', Fig. 59, and the image appears on the ground glass. This method, however, gives a very small image, and so the full equipment has an attachment whereby a Zeiss compensating eye-piece is fixed

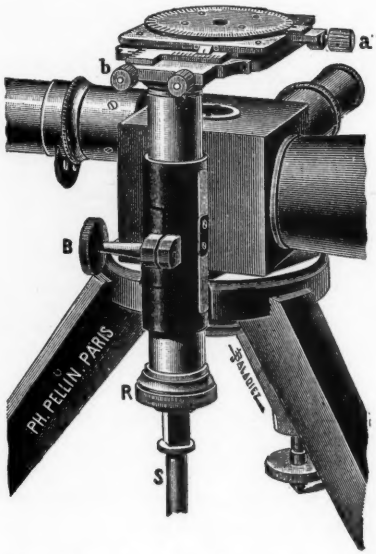

FIG. 60. Latest form of Le Chatelier microscope.

at the position of the ground glass of the small camera tube. To this is joined a camera fifty cm. or one m. long, which yields photographs $3\frac{1}{4} \times 4\frac{1}{4}$ inches and larger.

For rapid examination the Le Chatelier is to be recommended because the specimens require no mounting, and are always in focus.

ILLUMINATION.

For examination of specimens a Welsbach gas burner with bull's-eye condenser is very satisfactory up to about 500 dia's. Acetylene gas burners have also been used. For higher power work (and for photography above 250 dia's) an arc light becomes necessary. The arc lamp illuminating apparatus manufactured by Bausch and Lomb is excellent in every way. The Boston Testing Laboratories have improved it for metallographic purposes and their form is shown in Fig. 61. The lamp has a 90° arc with adjustments in three planes and works exceedingly well.

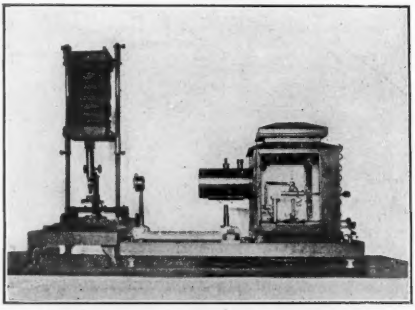

FIG. 61. Bausch and Lomb arc lamp illuminating apparatus as improved by the Boston Testing Laboratories.

The figure shows the condensing system and cooling cells, and, at the other end of the bench, is fitted an automatic shutter, iris diaphragm and colored screen holder.

Pellin has equipped an optical bench (for use with the Le Chatelier microscope), which consists of a strong cast-iron body with supports for camera, microscope, diaphragms, cells, condenser and Nernst lamp.

There are several forms of arc lights for illuminating purposes in microscopic work on the market. The 90° arc is by far the best because the beam of light remains constant in position, and does not move as the carbons burn down. An automatic feed is an advantage.

PHOTOGRAPHY.

The method of taking photographs is the same as that used for rock-sections. The microscope takes the place of the camera lens and any well-made camera can be used, provided it is firm and rigid. A sharp focus is obtained by means of a small watchmaker's lens. To obtain a sharper definition, a piece of thin glass is cemented to the center of the ground glass with Canada balsam, or, better still, five cover glasses are used, one in the center and one in each corner of the ground glass.

There are two methods of using the camera, viz., in the horizontal and in the vertical positions. With the Martens' stand and the Le Chatelier microscope the horizontal position is used, and in the former the specimen must be firmly attached to the glass slide and fixed on the stage. The camera can be of considerable length and the magnification proportionately increased.

When a vertical camera is used much less room is needed. Fig. 61 shows the 4×5 camera made by Bausch and Lomb, which consists of two rigid steel bars attached to a cross-piece which is hinged to a heavy metal base. The camera slides on the two metal bars and can be clamped in any position. One bar is graduated and by this means after calibration the magnification can be approximately determined. This instrument can also be used in the horizontal position if necessary. Photographs can be taken with or without the eye-piece. If the eye-piece is not used, the plates are often fogged by light reflected from the sides of the microscope tube. This can be overcome by using a cylinder of unglazed black paper or black cloth inside the tube. For high power work, projection eye-pieces will be found to give the best results.

As regards plates, for low magnification, the Eastman or Ilford ordinary give sharp images and enough contrast. With a magnification of say 80 diameters, vertical illumination with Welsbach gas burner, specimens like a mixture of pyrite and bornite require an exposure of thirty seconds. For higher power work, it is best to use orthochromatic plates and a color screen. Using an arc light, Forbes orthochromatic plates and a

yellow screen, a magnification of 250 diameters requires four seconds' exposure.

In photographing polished surfaces of minerals, color plays an important part, and objects which give a good contrast to the eye often show none in the negative, as, for example, chalcopyrite and pentlandite. If etching will not produce a difference, it becomes necessary to use screens.

In conclusion, it must be stated that the above account of methods of examining opaque minerals is not intended to be exhaustive, but is given from personal observation and trial as a guide to those who wish to begin work along this line. After a very little while each worker develops methods of his own which he finds far superior to all others.

The writer has to thank the Boston Testing Laboratories and Carl Zeiss for use of blocks for Figs. 57 and 61, and 56 and 58, and Ph. Pellin for Fig. 60.

To the Carnegie Institution of Washington he wishes to express his indebtedness for a grant for apparatus to carry on this work.

A MICROSCOPIC EXAMINATION OF THE COBALT NICKEL ARSENIDES AND SILVER DEPOSITS OF TEMISKAMING.

W. Campbell and C. W. Knight.

In the preceding paper[1] the methods employed in the microscopic examination of opaque minerals have been described and it is now intended to give the results of the application of these methods to the cobalt nickel silver veins of Temiskaming.

The geology of these deposits has been set forth in detail by W. G. Miller,[2] from whose work the following information has been abstracted.

OCCURRENCE.

The deposits occupy narrow practically vertical fissures or joints which cut through a series of usually slightly inclined metamorphosed fragmental rocks of Lower Huronian Age. A few veins of similar form have also been found in the adjacent diabase, whilst a few appear to be partly or wholly in the Keewatin which is in contact with the Lower Huronian.

The material in the veins has most probably been deposited from highly heated and impure waters which circulated through the cracks and fissures of the crust and were probably associated with the post-Middle Huronian diabase and gabbro eruption.

ORES AND MINERALS.

The more important ores in the veins are native silver—associated with which is usually some dyscrasite (Ag_6Sb), argentite, etc.—smaltite ($CoAs_2$), niccolite (NiAs) and related minerals.

At the surface occur the decomposition products cobalt bloom or erythrite ($Co_3As_2O_8 + 8H_2O$) and nickel bloom or annabergite ($Ni_3As_2O_8 + 8H_2O$).

[1] Campbell, Economic Geology, Vol. I., No. 8, pp. 750–765.

[2] "The Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming," Ontario, Report Bureau of Mines, II., 1905.

Most of the veins are very rich in silver and more or less calcite is present. Their width runs from one to eighteen inches. The ores are frequently grown together and the arsenides of cobalt and nickel are found intimately mixed with silver. At other times there is almost massive smaltite or niccolite. Cloanthite ($NiAs_2$) occurs characteristically in small spheroidal masses in calcite. The native silver is in masses, films and flakes, etc., and usually contains some antimony and occasionally bismuth. The dyscrasite is usually closely associated with native silver. Argentite occurs in a number of veins while native bismuth is found in all of the deposits.

One of the veins, the Cobalt Hill, does not carry silver in paying quantities, but consists of fourteen inches of practically solid ore—grains of copper-colored niccolite set in a gray groundmass of smaltite. Cloanthite is also present.

The specimens for microscopic examination were obtained from properties in the heart of the region and may be considered typical. In them a definite order of deposition is shown, as will be seen from the following illustrations.

RELATION OF SMALTITE TO NICCOLITE AND OF SMALTITE AND NICCOLITE TO CALCITE.

Spec. IV.—La Rose mine. To the eye the specimen consists of a dendritic growth of smaltite and niccolite, surrounded by a groundmass of calcite. Under the microscope the termination of the various fronds shows up as in Plate IX, Fig. 1. $\times$ 50 dias. Vertical (V) illumination. The interior consists of niccolite, but is not homogeneous, for in places it contains numerous spots of a bluish-white material which apparently separated out with the niccolite like an emulsion, or was precipitated from it in the solid state. The niccolite polishes extremely well.

Around the niccolite, like an envelope, occurs the smaltite, whose whitish cubes abut on the pinkish niccolite and are cut by veins of the latter. The smaltite is more difficult to polish and yields a surface rather rough in appearance.

Lastly we have the groundmass of calcite which with vertical light appears black. It surrounds the smaltite-niccolite dendrites

as a matrix, occurs as patches in the niccolite and between it and the smaltite and in the form of veins cuts both. Plate IX, Fig. 2 ($\times$ 80, *V*) shows, in the center of the field, a cube of smaltite surrounded by the smooth, pinkish niccolite. As before, around the niccolite occurs an envelope of smaltite, the whole being set in calcite, the black constituent.

Another specimen (No. 12) from the same locality showed the smaltite as cubes and rosettes, the niccolite without shape inclosing cubes of the former, while the whole is cut by veins of calcite, which also forms the matrix.

The above seems to show that smaltite was the first mineral to be deposited—that next came the niccolite, but not always pure, whilst later on the calcite was deposited, surrounding the whole as a groundmass and cutting it as veins, showing that the smaltite-niccolite was more or less disturbed and fractured before the deposition of the calcite. This establishes the order which is the same in all of the specimens examined.

It is somewhat surprising, however, that the niccolite occurs inside an envelope of smaltite. Were we dealing with an alloy of smaltite and niccolite which had solidified from the molten state, the explanation of the structure would be simple—smaltite crystallized out first, concentrating the remaining liquid in niccolite in the interior. To explain the structure from the view of deposition from an aqueous solution, one needs assume a cavity on the walls of which to precipitate smaltite, etc., then a removal of the mold and its replacement by calcite.

THE STRUCTURE OF THE SMALTITE.

In Plate IX, Figs. 1, 2, and Plate X, Fig. 4, we have the smaltite occurring as cubes and irregular masses or incrustations. It also occurs as well-marked rosettes, which, however, are far from uniform. Under the heading of smaltite-cloanthite, Dana states that cobalt and nickel are usually present and the two species grade into each other; that many analyses do not conform even approximately to the formula RAs_2, the ratio rising from less than 1 : 2 to 1 : 2.5 and nearly 1 : 3, showing a tendency towards

PLATE IX.

EXPLANATION OF FIGURES.

FIG. 1. Shows smooth interior of niccolite, surrounded by rough gray envelope of smaltite, the whole set in a dark calcite groundmass ($\times 50, V$).

FIG. 2. The same ($\times 80, V$). In center a cube of smaltite is embedded in niccolite.

FIG. 3. Rough gray smaltite in dark groundmass of calcite ($\times 70, V$).

FIG. 4. Rosettes of smaltite in light pink groundmass of calcite ($\times 70, O$).

FIG. 5. The same, showing a new constituent ($\times 70, O$).

FIG. 6. Deeply etched smaltite ($\times 33, V$).

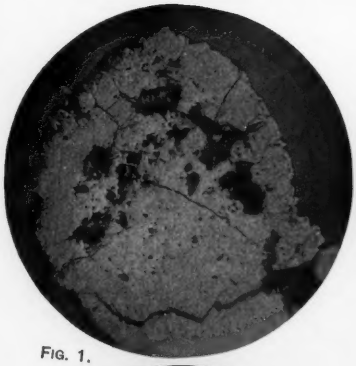

FIG. 1.

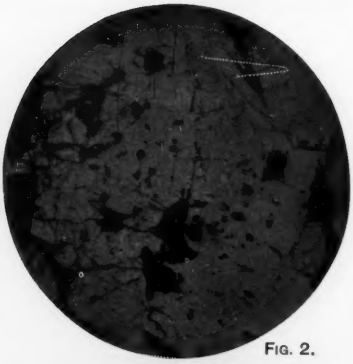

FIG. 2.

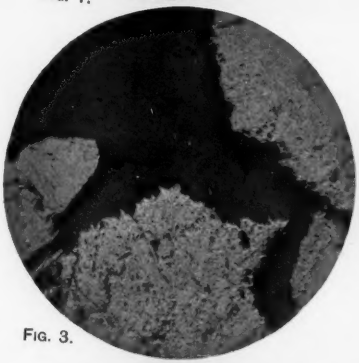

FIG. 3.

FIG. 4.

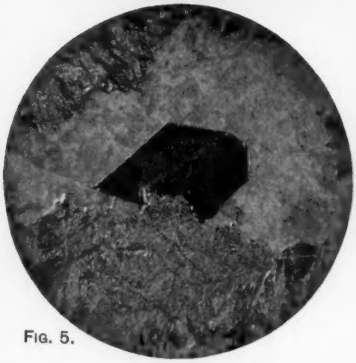

FIG. 5.

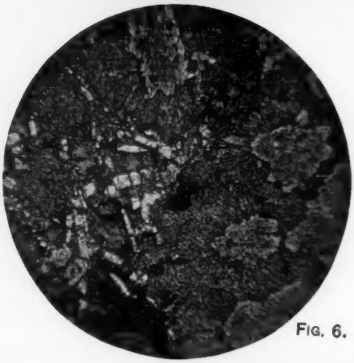

FIG. 6.

skutterudite, RAs_3, perhaps due to either molecular or mechanical mixture.

Spec. II, from la Rose mine, in the hand specimen showed rosettes of smaltite surrounded by calcite. The structure of the polished surface is shown in Plate IX, Fig. 3 ($\times$ 70, *V*), where the dark calcite forms a groundmass for the arsenide which on the lower right-hand side shows a fracture filled with calcite. On etching lightly, the structure of the rosettes is clearly developed. Oblique light, however, gives the best results, when the calcite appears a cloudy pink and the rosettes steely-gray. The structure is shown by Plate IX, Fig. 4 ($\times$ 70, *O*). When we contrast Plate IX, Figs. 3 and 4, the difference between vertical and oblique illumination is strikingly brought out. Etching also serves to reveal the presence of another form, as seen in Plate IX, Fig. 5 ($\times$ 70, *O*), which shows a dark crystal to have grown on a rosette before the deposition of the calcite. By vertical light before etching these crystals are hard to distinguish from the smaltite. One is seen in the left-hand of Plate IX, Fig. 3. On etching with nitric acid (1:1), the unknown material takes a straw tinge. A second specimen (No. 10) from the same locality showed similar crystals throughout the mass.

When we proceed to etch more deeply we find that the rosettes themselves are not uniformly attacked, as is shown in the following:

Spec. V, from Cobalt Hill, the non-argentiferous vein, showed when polished a structure similar to the last but with very little calcite. Etching reveals the presence of some lath-like crystals which had separated or crystallized out between the rosettes before the calcite had deposited. Deep etching seems to show that the center or kernel of the rosettes is different from the rest. This is shown in Plate IX, Fig. 6 ($\times$ 33, *V*), deeply etched, where the cores of the rosettes show up lighter, whilst between the rosettes lie the hard, white unetched lath-shaped crystals, most of which, however, are fractured. Plate X, Fig. 1 ($\times$ 80, *V*), shows the same, together with some calcite as a groundmass.

Two other specimens (Nos. 18 and 19) from the same locality

PLATE X.

EXPLANATION OF FIGURES.

FIG. 1. Deeply etched smaltite (× 80, *V*), showing some dark calcite in center, together with some white unknown crystals. The smaltite is not uniform.

FIG. 2. Pink calcite, black argentite, molded on the rough pyrite-like material (× 80, *O*).

FIG. 3. Rough smaltite in relief, embedded in bright white silver on one side and black calcite on the other (× 70, *V*).

FIG. 4. Rough smaltite in silver groundmass (× 70, *V*).

FIG. 5. Whitish silver vein in grayish argentite (× 88, *V*).

FIG. 6. White silver vein in dark calcite groundmass (× 60, *V*). Silver vein has thin blue border.

FIG. 1.

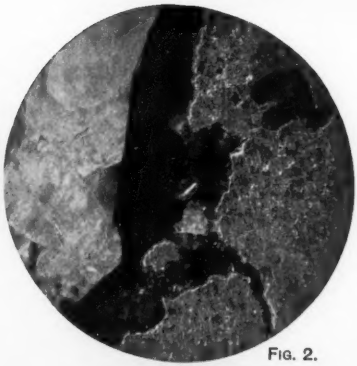

FIG. 2.

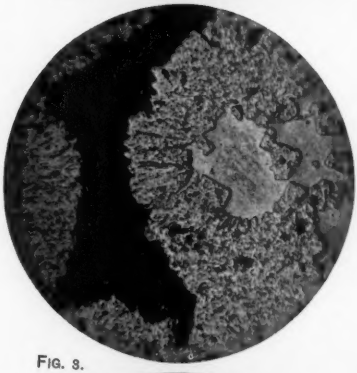

FIG. 3.

FIG. 4.

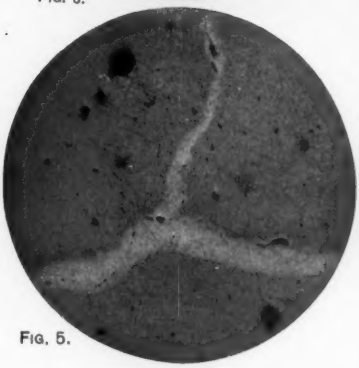

FIG. 5.

FIG. 6.

show the same variation in the smaltite, together with the presence of the lath-like crystals.

From the above it is seen how an apparently homogeneous mineral varies from the center to outside, and also contains other minerals as impurities so finely distributed through it that complete mechanical separation would be impossible. We can also understand how in this way analyses would vary, as recorded by Dana.

RELATION OF THE CALCITE TO THE ARGENTITE.

Spec. VIII, from la Rose mine, consisted of soft, sectile argentite and calcite. The argentite occurs as polygonal masses surrounded by calcite and also as veins cutting the latter. In places the argentite is seen to fill cleavage cracks in the calcite and is therefore later. In addition, there occur one or two small masses of pyrite-like material, which may be older than the calcite, and certainly is older than the argentite which surrounds it and veins of which cut across it. The relationship of these three constituents is shown by Plate X, Fig. 2 ($\times 80, O$). On the left we have pinkish crystalline calcite inclosing a black mass of argentite which is molded on and cuts the pyrite-like material.

A second specimen (No. 10) from the same mine shows very fine veins of both silver and argentite cutting the calcite, clearly showing that the latter was the oldest constituent of the three.

RELATION OF THE SMALTITE AND NATIVE SILVER.

Spec. I shows in the hand specimen a mass of smaltite and calcite inclosing veins of native silver, clearly showing the latter to be the youngest. In places the native silver is seen as the matrix of the cubes of smaltite. Plate X, Fig. 3 ($\times 70, V$), shows the hard, rough smaltite as rosettes, etc., surrounded by a dark groundmass of calcite, but inclosing (on the right of the Fig.) a groundmass of later native silver. This silver groundmass is better shown in Plate X, Fig. 4 ($\times 70, V$), where it encloses more or less perfect cubes of smaltite. Here again it seems strange that the rosettes of smaltite should be surrounded by calcite, while the cubes are imbedded in native silver (cf. relation to the niccolite, Plate IX, Fig. 1).

Associated with the silver are two metallic substances, one with a bluish tint, the other mauve. (According to Miller the native silver is usually found to contain some antimony and occasionally bismuth.) These two substances are always without crystalline form, being of the same generation as the silver. Spec. II, from la Rose mine, shows the same structures as described above and is shown in Plate X, Figs. 3 and 4. In specs. 13 and 14, from the same locality, the silver occurred in large patches and in veins cutting the fractured smaltite and calcite. Spec. 12 contains two fragments of rock in which the silver is impregnated.

RELATION OF THE CALCITE AND NATIVE SILVER.

Spec. III, from the Trethewey mine, consists of veins and irregular masses of silver in calcite. Some rosettes of smaltite occur and show the same relations as described above. Plate X, Fig. 6 ($\times$ 60, *V*), shows an irregular vein of native silver penetrating a mass of calcite. The silver is associated with a bluish constituent which here surrounds it as an envelope and also occurs in it as small, irregular masses. Veins of silver in calcite were found in many of the specimens (I, 10, 13, la Rose mine), whilst in specimen 12 from la Rose mine the bluish envelope between the silver and the calcite was very marked.

RELATION OF THE ARGENTITE TO THE NATIVE SILVER.

Spec. VI, from the Buffalo mine shows three veins of silver in a groundmass of argentite. On the corners of the specimen are small patches of calcite. Owing to the softness of both argentite and silver it was almost impossible to obtain a surface free from scatches. Plate X, Fig. 5 ($\times$ 88, *V*), shows a ramifying vein of silver in a groundmass of argentite. The contrast in the photograph is weak, but under the microscope the two are easily distinguished, first by their yellowish and bluish tints respectively, and secondly by the extreme softness of the argentite. On exposure to the atmosphere the silver tarnishes red to pink in color.

THE RELATION OF THE BISMUTH TO THE NATIVE SILVER, ETC.

Several specimens rich in bismuth were polished and examined and although it seemed clear that the bismuth was later than the calcite, the relative ages of the bismuth and native silver were not so easily determined.

One specimen (No. 15) of massive bismuth showed an island of silver which polished in slight relief. Within the silver were small patches of niccolite and smaltite in their usual order, the smaltite occasionally showing well marked faces. On etching the specimen with nitric acid (1:1) the bismuth showed up as two large crystals full of slip-bands due to strain, the silver as a single crystal also containing numerous slip-bands. It seems probable that the strain occurred during mining operations.

Another specimen (No. 16) showed cubes of smaltite set in niccolite grains and patches and in calcite, these three constituents showing their normal order of succession. In addition the specimen contained both silver and bismuth. The bismuth included cleavage fragments of calcite and also cut it as veins, proving its later origin. The relation of the bismuth to the silver is difficult to make out because although silver frequently occurs as patches within the bismuth and is associated with smaltite and niccolite, occasionally we find small patches of bismuth within the silver. The close association of the smaltite and niccolite with the silver, however, seems to show that the bismuth was the latest constituent.

ORDER OF SUCCESSION.

Although *all* of the structures met with in this examination can not be satisfactorily explained, they point to the following order of origin for the principal constituents: First came the smaltite, closely followed by the niccolite; other minerals in small amount came down at this time. Then after a period of slight movement in which the first minerals were more or less fractured, calcite was deposited as a groundmass. Later came argentite which was followed by native silver and native bismuth. Lastly came the surface decomposition products erythrite and annabergite.

Arranged in tabular order the succession is then as follows:

SMALTITE,
NICCOLITE,
Period of movement and fracturing.
CALCITE,
ARGENTITE,
NATIVE SILVER,
NATIVE BISMUTH,
Period of decomposition.
ERYTHRITE and ANNABERGITE.

If a sample of the ore is melted under borax and slowly cooled a button of speiss is obtained whose fracture resembles smaltite. On polishing and examining under high powers, dendritic crystals resembling smaltite in color and hardness, etc., are seen set in a metallic groundmass like silver. In places in the groundmass occur threads and patches with a purple color, the whole closely resembling a eutectic structure. The resemblance of the whole to Plate X, Fig. 4, a structure due to deposition from aqueous solution, is marked.

The presence of bismuth gives us some idea of the temperature during deposition of the ore. Bismuth melts at 269° C. at normal pressure. Provided the pressure remained the same (in ore-bearing solutions, however, it is doubtless great) the solution depositing the bismuth must have been below 269° C., otherwise the bismuth would come down as a molten metal and alloy with the silver already present; which, as we have seen, it did not do.

In conclusion, it may seem that the work is incomplete because two unknown minerals occur with the smaltite and then the silver contains impurities as yet undetermined. But the object of the work was to determine the order of succession of the chief constituents, smaltite, niccolite, calcite, argentite and the native metals, silver and bismuth—and this has been done.

The thanks of one of us are due to the Carnegie Institution of Washington, D. C., for a grant for apparatus and material.

THE DIRECTIONS OF MOVEMENT AND THE NOMENCLATURE OF FAULTS.

FREDERICK LESLIE RANSOME.

It is not the special purpose of this paper to record observations or deductions new to science. The facts presented may be familiar to many geologists and it is possible that others than the writer may have drawn from them deductions similar to those here offered. The object of this note is primarily to direct the attention of geologists and particularly of economic geologists, to whom the phenomena of faulting are of exceptional importance, to certain assumptions involved in the common treatment and accepted nomenclature of faults and to emphasize the importance of a kind of dislocation that hitherto has received but slight consideration from all but one or two workers.

If the present paper will serve further to initiate a discussion that may ultimately prove fruitful in a more scientific classification and nomenclature of faults than that now in use, it will have fully attained its object.

Faults are usually defined as fissures or rents in the earth's crust, where one side has moved relatively to the other. It is commonly assumed, possibly in part from an unconscious retention of primitive notions of a thin crust floating upon a liquid interior, and in part from a habit of thinking of faults in cross section, that the direction of motion is given by the line of perpendicular intersection of the fault plane by a vertical plane which, in most text-book illustrations of faulting, is the plane of the paper. In other words, one side of the fault is supposed to have slipped up or the other down. Upon this assumption is based the classification of faults as *normal* and *reverse* or *overthrust,* normal faults being those in which the hanging wall has apparently gone down relatively to the foot-wall and reverse faults being those in which the relative movement has apparently

been of the opposite kind. A further consequence of the same assumption is the dictum that normal faulting implies stretching of the earth's crust and reverse faulting compression. Le Conte, for example, states that 'where fissures are formed by lateral pressure or crushing, reverse faults are formed; but where they are formed by lateral tension or stretching, normal faults are formed."[1] Chamberlin and Salisbury[2] remark that "in view of the current opinion that the crust of the earth has been subjected to great lateral thrust as a result of cooling, it is well to make especial note of the fact that the faults which imply *stretching* are called *normal* because they are the more abundant; and that faults which imply thrust are less common, and are styled *reversed*." Van Hise[3] classifies faults as tension faults and compression faults, or preferably as gravity faults and thrust faults. In fact, the correlative ideas that normal faults are necessarily due to a slipping down of the hanging wall under the direct influence of gravity and that they necessarily imply stretching or extension have been so generally held that they have been incorporated into widely accepted genetic terms and definitions applied to the actual phenomena.

The fact that faulting does in most cases produce a heave or offset in beds or other anterior structures, as seen in relation to the fault on any approximately horizontal plane, such as the surface of the earth or a mine level, has been known from the earliest days of geology. The first and obvious impression made by such an offset upon an observer not familiar with geological structures or literature is that the separated ends of the beds have been shoved past one another by horizontal movement along the fault. Geologists soon found, however, that the offsets are in many instances due to the effect of approximately vertical movements upon inclined strata and this explanation, undoubtedly the true one for many occurrences, has been so generally adopted as

[1] "Elements of Geology," 3d ed., 1891, p. 234. In the 5th ed., revised by H. L. Fairchild, the words *gravity or tension* are substituted for *normal*.

[2] "Geology," Vol. I., 1904, pp. 497–498.

[3] "Principles of North American pre-Cambrian geology," 16th Ann. Rept. U. S. Geolog. Survey, 1896, pt. i., pp. 672–674.

to partly close the minds of geologists to other suggestions. Green,[1] after showing how the heave of faults may be explained by vertical displacement, remarks that "it must not be assumed that the displacements produced by faults are always wholly vertical; it is conceivable, nay highly probable in those cases where the rocks have been subjected to powerful horizontal compression, that horizontal motion may have taken place, and that beds may have been moved not only up and down, but also to and fro on opposite sides of a fault."

Jukes-Brown,[2] after the usual explanation of heave or offset, adds the following foot-note: "It is possible, however, that some dislocations may really be lateral shifts without any vertical displacement. These may be called *heaves,* and they appear to occur in districts that have been much disturbed and fractured; see 'Reports of Miners' Assoc. of Cornwall and Devon, 1879, Phenomena of Heaves,' by A. T. Davies." Margerie and Heim[3] also, in their useful compendium of faulting, consider transverse horizontal faults or shifts (décrochments horizontaux) and point out how in some cases they may be distinguished from faults in which the vertical component predominates. Most modern textbooks on geology, however, pay scant attention to the possibility of horizontal shifting. Sir Archibald Geikie[4] and Chamberlin and Salisbury,[5] for example, in their respective textbooks classify faults as normal and reverse and discuss them as if the motion were always in a vertical plane perpendicular to the fault plane. Horizontal shifts or heaves are not even mentioned. Dr. James Geikie, however, devotes a paragraph to "transcurrent faults or transverse thrusts" He states that "faults of this kind are steeply inclined or vertical, and often extend for many miles, always traversing the strata at approximately right angles to the strike. They are neither downthrows nor upthrows, movement having taken place in a forward direction so that the walls

[1] "Physical Geology," 3d ed., London, 1882, pp. 497–498.
[2] "Handbook of Physical Geology," London, 1884, pp. 359–360.
[3] "Les dislocations de l'ecorce terrestre," Zurich, 1888, pp. 71–76.
[4] "Textbook of Geology," 4th ed., London, 1903, Vol. I., p. 690.
[5] "Geology," New York, 1904, Vol. I., p. 493.
[6] "Structural and Field Geology," Edinburgh, 1905, pp. 168–169.

of the thrusts are slickensided horizontally. Not infrequently the rocks on either side are much crushed and shattered, or the two walls may be separated by a 'friction breccia.' Among the best known examples of such transverse thrusts or transcurrent faults are those met with in the Alps and the Jura."

Mr. J. E. Spurr, who has perhaps done more than any other recent writer to clarify the subject of faulting, writing in 1897, remarked: "Whenever the rocks of the earth's crust are subjected to strain, fractures take place in them as in any other body under similar conditions, and the different parts of the rock tend to move past one another along the fracture-planes, seeking to obtain relief from the strain and to accommodate themselves to new conditions. In this movement one part of the fractured rock-mass may move upon the other in any direction, up, down, sidewise or obliquely, according to the conditions, which are different in each instance. . . . The throw is always a part of the total displacement, although with no definite relationship to it, and varies from zero to the full total displacement."[1] In his later writings, also, he has consistently regarded faulting from an exceptionally broad standpoint and, in contrast to most geologists, has recognized the importance of the horizontal element in many steep faults. In his textbook[2] he calls attention to the fact that vertical cross sections do not necessarily show the principal movement of a fault and illustrates by a stereogram a horizontal fault (heave) where throw and offset coincide. In his report on the Tonopah district[3] he describes and illustrates faults in which "blocks on the west side of the separate northeast faults were shoved northward past the blocks on the east side, nearly horizontally, but with a slight downward plunge." Spurr and Garrey[4] also describe nearly horizontal movements along steep fault planes in the Georgetown district, Colorado.

In the course of studies carried on by me during the past few

[1] "The measurement of faults," *Journal of Geology*, Vol. 5, 1897, pp. 723 and 728.

[2] "Geology Applied to Mining," New York, 1904, pp. 151 and 158.

[3] U. S. Geolog. Survey, Professional Paper No. 42, 1905, p. 144.

[4] Preliminary report on ore deposits in the Georgetown, Colo., Mining District, U. S. Geolog. Survey, Bull. 260, 1905, p. 109.

years in mining districts in Arizona and Idaho it has been found that faulting plays a very important part in the structure. In the Globe and Bisbee districts in Arizona, for example, faults are extraordinarily abundant and the main structural features are far more a result of dislocation than of folding. The Coeur d'Alene district in Idaho is traversed by many great faults with lengths up to thirty miles or more and throws which in some instances amount to eight thousand feet.

In all three districts both normal and reverse faults are present and inasmuch as both classes of faults appear to belong to the same general period of dislocation it is difficult to account for their association so long as the mind is unconsciously bound by the prevalent view that normal faulting necessarily implies stretching. In the Bisbee district,[1] for instance, low angle overthrusts with displacements up to two miles are accompanied by nearly vertical faults which in great part are of the normal type although some are steep reverse faults. The reverse faults are unquestionably due to compression, and while tensional stresses might be set up as a minor feature in the general compression of a heterogeneous mass of rocks, it does not seem probable that numerous and important normal faults can be formed merely as a result of such subsidiary tension. Thus, if normal faults necessarily imply stretching, we must conclude that they were formed at different times from the reverse faults and that the rocks in such a district as that of Bisbee were alternately stretched and compressed, which is difficult of belief.

In the Coeur d'Alene district great normal faults are associated also with numerous and important reverse faults. Most of the latter are steep but some have dips probably under rather than over forty-five degrees. The faults all appear to belong to one general period of dislocation although it would not be possible to prove that normal and reverse faults were actually produced at the same time. The fact, however, that both kinds of faults occur in the same parallel systems is strongly suggestive of practically simultaneous origin. The steep reverse faults are

[1] See Ransome, F. L., "The Geology and Ore Deposits of the Bisbee Quadrangle, Arizona," U. S. Geological Survey, Professional Paper No. 21, 1904.

in this region particularly puzzling if one entertain the supposition that the motion has taken place in accordance with the familiar textbook representation. Horizontal stresses exerted at right angles to the strike of a fault do not seem adequate to account for the thrusting of one wall up an inclined plane of sixty or more degrees.

These difficulties largely disappear when we consider that motion along a fault plane is not necessarily up or down its slope, but may be a horizontal shove of one wall past the other; or the direction of motion may form any angle with the horizontal line representing the strike of the fault. Faults of this type have been recognized in the Alps, in Cornwall, and by Mr. Spurr in mining districts in Colorado and Nevada, as already mentioned; but they seem to have been commonly regarded as exceptional occurrences of so little importance as not to deserve mention in most of the leading manuals of geology. It is believed, however, that when observers become watchful for dislocations of this character they will prove to be less rare than had been supposed. Recent studies by me in mines in the Bullfrog district, Nevada, have shown fault striations which are more nearly horizontal than vertical, and Mr. J. E. Spurr[1] finds that in the Georgetown region of Colorado evidence of nearly horizontal movement along many of the faults is particularly clear, as he will show in a forthcoming publication on the geology and ore deposits of that district. Most impressive of all, however, is the recent displacement along the San Andreas fault which was the immediate cause of the San Francisco earthquake. According to the preliminary report[2] of the State Earthquake Investigation Commission, the southwest side of the fault, for a distance of at least one hundred and eighty-five miles was shifted to the northwest relatively to the northeast side of the fault. The maximum horizontal displacement observed is about twenty feet, whereas the maximum vertical displacement does not exceed four feet. This occurrence shows that heave faults are not necessarily transverse to the strike of the rocks, as Dr. James Geikie

[1] Oral communication.

[2] Pamphlet, without date or place of publication.

states, basing this generalization doubtless upon the transcurrent faults of the Alps and Jura. The California dislocation traverses a complex structure, but on the whole runs parallel to, rather than across, the dominant orogenic axes.

Whether heave faults are numerous as compared with those of approximately vertical throw is something that only careful future observation can decide. The fact that they occur is certain, and this is enough to invalidate the assumption which has already been referred to as vitiating most descriptions and discussions on faulting. An essentially vertical displacement has been premised in probably 99 per cent. of the high angle faults described. As a matter of fact there is nothing to show that a considerable proportion of the so-called normal or reverse faults noted in geological literature should not be classed as heave faults, or at least as faults in which the horizontal component of motion measured in the plane of the fissure is as great or greater than the vertical component.

The significance of the terms normal and reverse as applied to faults now requires some attention. In the following diagrams an attempt has been made to illustrate some of the effects produced by faults in which there is an *actual* heave, not the apparent heave or offset produced by normal or reverse faults of the conventional type. Fig. 62 represents a cube of rock traversed by the fault plane *FF* and by the stratum or dike *BB*. The block may be supposed resting upon a table. In Fig. 63 the block is faulted by slipping the front portion to the left. The fault is a heave, the vertical component, or throw, being zero. It will be observed that the dislocation would ordinarily be classed as a normal fault, the part of the bed in the hanging wall having apparently slipped down. A careful student of text-book faulting, if he encountered a dissevered bed in this position would doubtless assume a normal throw and readily explain the offset as an apparent heave, or simply "heave," as the word is commonly and unfortunately used, with tacit implication that the horizontal movement is apparent—not real. In this case, cognizant of the table top under the block, we reverse the process and account for the throw as apparent only. In Fig. 64 the

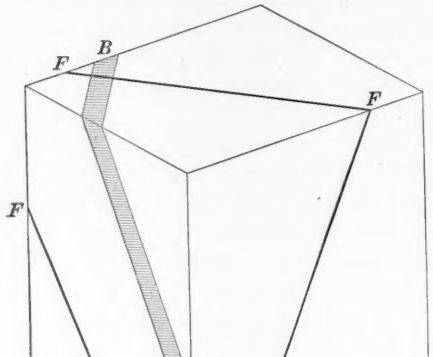

FIG. 62. Block before faulting. *FF*, fault plane; *BB*, bed or dike.

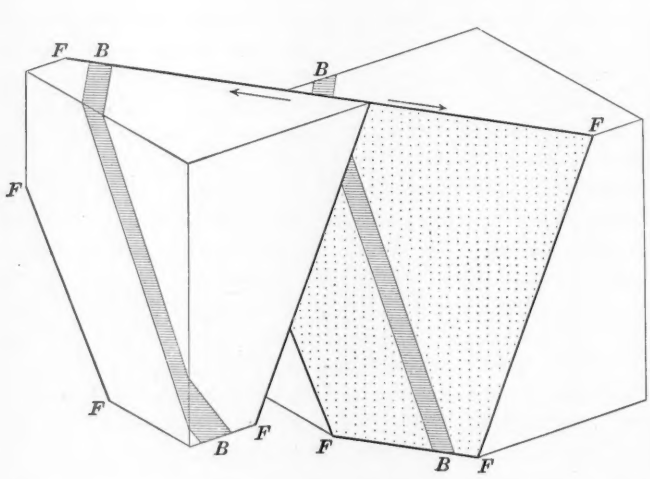

FIG. 63. Block dislocated by heave fault, showing apparent normal faulting of bed *BB*.

front part of the block is slipped to the right, giving what would ordinarily be termed a reverse fault, although there has been no vertical movement whatever. In Fig. 65 the front piece of the block is slid up along the fault plane and raised above the surface of the table. Here, it will be noted, the fault as measured by the apparent throw of the bed *B* would be classed as a normal fault and yet the actual movement is partly a heave and partly an upthrust. Other variations might be diagrammatically illustrated but those shown are enough to demonstrate the fact that along a plane of dislocation, within which the horizontal component of movement exceeds that corresponding to the dip, apparent normal faults may occur at some points and apparent reverse faults at others. Whether a purely horizontal displacement appears as a normal fault or as a reverse fault at any one place depends merely upon the attitude of the beds (or other structures used as datum planes) relative to the plane of the fault. Furthermore "normal faults" and "reverse faults" may both be produced simultaneously by compression and "normal faulting" is not necessarily a proof of tension.

In short, the terms normal and reverse as commonly applied to faults have very little real significance. They express merely a local relation of the faulted beds, dikes, or other structures to the plane of the fault. They do not, unless we make an unwarranted assumption, indicate the kind or direction of the movement or whether tension or compression was the dominant stress at the time of dislocation. It is only when, by the study of striations or of the broader structural relations of the field, the direction of the faulting movement is determined, that we are in a position to discuss the question whether the faults are of a kind that imply compression for their production or whether they are essentially of tensional origin. In regions of nearly horizontal beds it may be comparatively easy to decide that vertical movements have predominated over horizontal displacement, for it is evident that to produce a given throw in such rocks by nearly horizontal shifting, would require a much more extensive fault than one in which the displacement is nearly vertical, and corresponds to the visible throw. But with highly folded and

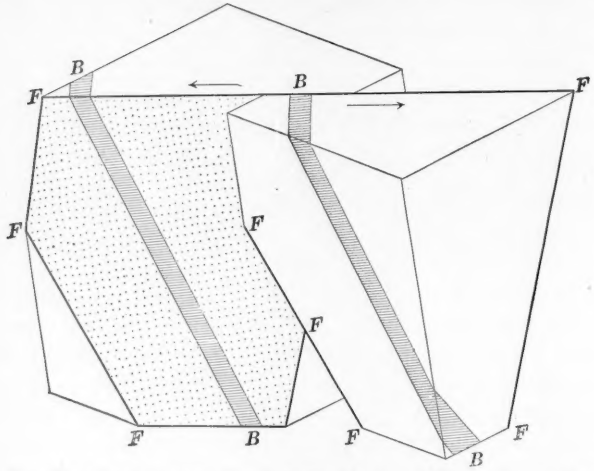

FIG. 64. Block dislocated by heave fault, showing apparent reverse faulting of bed *BB*.

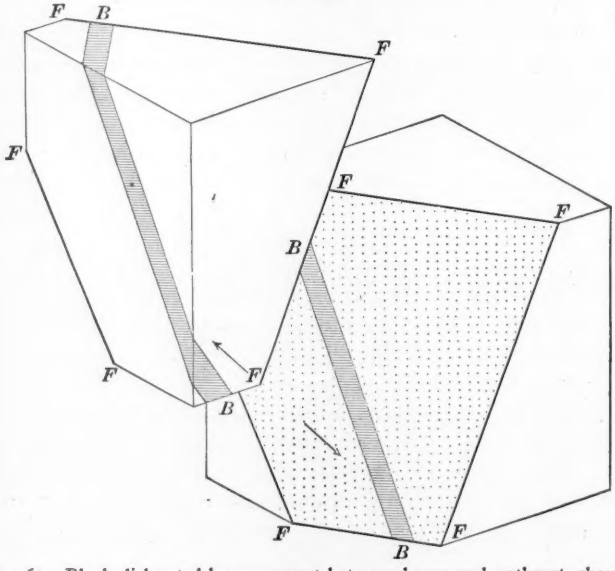

FIG. 65. Block dislocated by movement between heave and upthrust, showing apparent normal faulting.

much disturbed strata the determination of the relative importance of the horizontal and dip components of a fault becomes more difficult. Even where striae are found these have usually been graved by the latest movement along the fault plane, and may or may not be coincident in direction with the movement which effected the principal dislocation. While of course no geologist can doubt that many, and probably most, so-called normal faults are produced by the slipping of the hanging wall down in the general direction of dip and that such movement implies local tension or extension of the earth's crust, yet it is possible that careful study of faults will greatly lessen the apparent preponderance of faults of this type and bring the general phenomena of faulting more into harmony with the evidence furnished by thrust faults and folds for the dominance of compressive stresses in the lithosphere.

Several questions of nomenclature are suggested by the foregoing discussion. Are we to apply the term normal fault to the thing actually observed, irrespective of genesis, or are we to reserve it for those faults in which the hanging wall not only appears but is known to have slipped down relatively to the foot-wall? Are we to describe as a reverse fault one in which a certain bed appears as a higher point in the hanging wall than in the foot-wall or are we to reserve the name for dislocations in which it is known that the hanging wall has been actually upthrust relatively to the foot-wall? Evidently such terms as "gravity fault" and "tension fault," with their genetic connotations, are applicable only to those dislocations in which the direction of motion is known, not arbitrarily assumed.

THE MAXIMUM DEPOSITION OF COAL IN THE APPALACHIAN COAL FIELD.[1]

GEORGE HALL ASHLEY.

INTRODUCTION.

Much discussion has from time to time appeared on the various problems connected with the origin and deposition of coal, but it has seemed to the writer that sufficient careful work has not been expended on the amount of time involved in coal formation. The following paper is the first of three dealing with the time interval involved in the laying down of the coal of the Carboniferous. These papers will make no pretense at finality, but are prepared in the hope that their appearance, by suggesting a possible solution of a problem of great scientific interest, may call forth criticisms, suggestions and facts that will aïd our general understanding of the question. It is also hoped that they may develop a method of approach that will yield closer and more reliable results than those previously obtained. It must be confessed at the outset that the argument presented is based on a premise that is not wholly satisfactory. It has proved more so than any other, but is still accepted with an expressed doubt as to the limits of its applicability and a fear that the relative value of all of the factors involved has not been fully recognized. This premise is the so-called peat-bog theory, the only one of the many theories of coal formation so far presented into which time elements may be safely introduced. Any drift or water deposit theory involves indeterminable time factors.

A peat bog is the result of growth involving time. By eliminating the slow-growing bogs or those of whose rate of growth we know little or nothing, there still remain many cases on record in which we know the number of years required to produce a given depth of peat. By again eliminating those showing

[1] Published by permission of The Director of the United States Geological Survey.

the slower rates we may reach a figure which may fairly represent the maximum rate of growth of peat to-day. Any estimates made on those figures can of course claim no more than the presentation of values in terms of present conditions, but they are of value in furnishing a time factor which may serve a useful purpose in the comparison of present with past conditions.

The proposition may then be stated as follows: if we know (1) the maximum rate of peat formation; (2) the ratio of peat volume to the resulting coal volume; and (3) the maximum coal deposition in any period—we can then estimate the time required for the laying down of the coal of that period (in terms of present conditions).

As the third element of the problem is the most definitely known it will be taken up first. For the purpose of this paper it is proposed to limit the inquiry to the Pennsylvanian system as developed in the Appalachian coal field.

THE MAXIMUM DEPOSITION OF COAL IN THE PENNSYLVANIAN SYSTEM.

The Pennsylvanian system is composed of the following groups and formations:

DUNKARD GROUP—GREENE AND WASHINGTON FORMATIONS,
MONONGAHELA FORMATION.
CONEMAUGH FORMATION.
ALLEGHENY FORMATION.
POTTSVILLE GROUP, WITH MANY LOCAL FORMATIONS.

The individual members making up the formations of the Pennsylvania series show a marked tendency to gain in regularity in ascending the series. Again our knowledge of the Pottsville is more limited than of the higher formations. In estimating the thickness of coal in the Pottsville the method has been followed of summing up the maximum thickness of the several coal beds of different known regions and taking the one yielding the largest results. It is thus possible to deal with a maximum time interval. In studying the higher formations the plan has been to follow each coal bed over its area of recognized distribution, noting the thickness and then adding together the

maxima of the several beds. In examining the Allegheny formation something of a compromise between the two methods has been necessary as the conditions prove to be intermediate between the two extremes. The anthracite region will be separately considered. Cannel coals have been excluded because of the dubious character of the conditions under which they were formed; also pockets of coal that might have been due to local accumulations, and not grown *in situ*.

POTTSVILLE COALS.

Our knowledge of Pottsville coals is incomplete, certain portions of the group being better known in one locality, others in another. The Pottsville group attains its great development in the middle and southern Appalachians, and while much of the territory has been examined in reconnoissance, it is only here and there that a detailed study has been made. The Federal Geological Survey has done most of its detailed work in the southern Pottsville and a glance at one of their key maps reveals how scattered such work has been. A comparison of these scattered fields seems to indicate that the greatest total thickness of coals yet worked out is in the neighborhood of Cumberland Gap, where Kentucky, Tennessee and Virginia adjoin one another. A better knowledge of the Kanawha—New River—Pocahontas fields may some day locate the maximum deposition at a different locality.

The Pottsville in the Cumberland Gap region has a thickness of four thousand feet. Coal has been recognized at practically fifty horizons in this interval; at forty-four of these measurements have been made. These show a total maximum thickness of one hundred and fifty-eight feet. Subtracting the thickness of all partings there is left one hundred and thirty-four feet of solid coal. This estimate was obtained by taking the measurements of the different coals in Bryson mountain. As nine of the coals of recognized correlation are thicker in other parts of the same field, these measurements were correspondingly increased.

ALLEGHENY COALS.

The Allegheny formation is generally recognized as having seven widespread horizons. The recent work of the U. S. Geo-

logical Survey in Pennsylvania has shown that many of the coals correlated with one another in separated localities and therefore supposed to have been formed at the same time, are not in reality continuous. As an instance, the coals of the Upper Freeport and Lower Kittaning horizons may be cited. In such cases exploration has proved that coals long supposed to be continuous with one another are actually at slightly different horizons, the two levels often overlapping. Furthermore, many of the diamond drill records show an excessive number of coals, sometimes five or six extra coals being found in a single drilling. The same thing is sometimes recognized in surface outcrops, as in the case of the middle Freeport coal at Freeport, and other well known examples.

By tracing each of the principal beds over its recognized area and ascribing to it a thickness equal to that shown in its maximum development, a total maximum thickness is obtained of seventy-two feet; or allowing 25 per cent. for partings, of fifty-four feet of solid coal. In considering these figures, which will seem large to many, it must be remembered that many of the coals which over large areas are thin and insignificant become locally very important. Thus the great Hocking Valley coal of Ohio, a fourteen-foot bed, is correlated with the middle Kittanning coal which is generally of no economic value. So, too, the Upper Freeport coal is very thick in the Broad Top field of Huntingdon County, yielding locally eleven feet of coal in a total thickness of thirteen or fourteen feet. The Lower Freeport is locally fourteen feet thick in parts of the Reynoldsville field and almost as thick elsewhere.

CONEMAUGH COALS.

The Conemaugh coals are generally thin and non-workable. At least eleven horizons have been recognized and a majority of these acquire a workable thickness in some part of the area underlain by the formation. An examination of these confined to Maryland shows a maximum total thickness of coal, excluding partings, of over thirty-seven feet.

MONONGAHELA COALS.

The Monongahela formation contains six well recognized coals, including the important Pittsburg coal. Tracing these coals, as before, over Pennsylvania, Ohio, Maryland and West Virginia, they yield a total thickness of over thirty-two feet of coal without partings. If partings be included the totals are much higher, as the Pittsburg coal alone in parts of the George's Creek field of Maryland is over fifteen feet thick. The Waynesburg coal yields seven feet of coal at many places in Washington and Greene counties of Pennsylvania in a total thickness approaching fifteen feet.

THE DUNKARD COALS.

The Dunkard group, which is best developed in the southwest corner of Pennsylvania, contains at least six coals, only one of which, the Washington, is of workable thickness. The maxima of these coals yield a total of over sixteen feet.

SUMMARY.

A summary of these various estimates may thus be presented which, while not yet wholly satisfactory, will give a fairly good idea of the maximum deposition of coal in the Appalachian field.

SUMMARY OF MAXIMA OF BITUMINOUS COALS (EXCLUDING PARTINGS):

	Feet.
Dunkard	16
Monongahela	32
Conemaugh	37
Allegheny	54
Pottsville	134
	273

According to these figures the time involved in the laying down of the bituminous coal beds of the Appalachian coal fields has been sufficient for the deposition of a bed of coal at least two hundred and seventy-three feet thick. More complete investigation in the future will rather enlarge than decrease this figure, probably raising the total to more than three hundred feet.

The anthracite field was studied in the same way. The

writer's lack of personal acquaintance with this field led him to be conservative in view of the possibility of the maximum measurements in many cases being the result of the subsequent folding and not of the original deposition. Thus, the Mammoth bed, which usually is from twenty to thirty feet or less in thickness, measures in one place one hundred and fourteen feet with one hundred and five feet of coal. The plan has been followed of taking the highest average thickness for small districts. In this way a total maximum thickness was obtained of about two hundred and sixty feet, yielding a little over two hundred feet of solid coal, if the partings are considered to occupy 20 per cent. of the total. These figures include a thickness of fifty-six feet (forty-two feet of coal) for the Mammoth bed (Pottsville region), and forty-five feet for the Lyken's Valley coals, thirteen in number (at Lincoln and Kahina). If the extreme maximum measurements of each of the beds were taken the total would be much higher, but for the reason given that has not been done. In general, the maxima in the two fields are not far apart, and considering the limited extent of our knowledge, it seems fair to consider that as a maximum the equivalent of three hundred feet of solid coal was laid down during Carboniferous time. This figure will be used in the following papers.

EDITORIAL

THE RECORD OF GEOLOGICAL INFORMATION.

A year has now passed since the first issue of the journal ECONOMIC GEOLOGY was published. The editors expressed in the initial editorial the earnest hope that they might be aided in their efforts by the support of those who were interested in the science of economic geology, or engaged in the actual practice of mining. It is a source of great gratification to them that this hope has been more than realized, and as the present issue goes to press it has seemed appropriate to them to express to their readers and subscribers their keen appreciation of the cordiality and genuine interest which has been so generally extended. It is with somewhat unusual pleasure that they refer to the efforts which many busy men have made to contribute to the journal, because in the field of economic geological work and of mining engineering especially the multitude of business matters which press upon men occupied with large practice leaves little opportunity for writing. Contributions sent for the furtherance of scientific progress—those pleas for the greater exactness of geological research upon which so much of the success of modern mining is coming to depend—can only be attempted in odd moments gleaned, often at some sacrifice, from the stress of more important affairs.

From men so engrossed with practical duties have come many of the most valuable contributions, and from them, as they may find the opportunity and have the wish to write, will continue to come such contributions as can be offered only by those whose constant presence on the ground furnishes opportunities of recording facts that are open to no other class of observers.

It is one of the most serious obstacles to the progress of mining geology that the period during which geological conditions may

be observed is of such short duration. The solution of the problems of economic geology is so often dependent upon the data obtained in artificial excavations that this time factor is rarely appreciated by those whose work is carried on chiefly above ground. In the latter case the evidence is furnished by conditions on the surface and there need be no haste to complete the work, for in the course of many years the evidence will suffer no obliteration; outcrops which are to be observed to-day may be observed to-morrow, a year hence, fifty years hence; no limit is set other than that imposed by inclination or the necessities of the work. With the mining geologist this is not true. Outcrops are all artificial and are eminently transitory in their nature. The facts which may be observed to-day were but yesterday revealed and will to-morrow be as hopelessly lost. Mining operations are now conducted with such rapidity that few portions of any mine are long open to observation. The continuation of the work either removes the material which served as the basis for observation or buries under masses of débris and waste the enclosing rock, or the collapse of workings that quickly follows upon the heels of abandonment leaves forever inaccessible important clues to structure—clues which too often prove in later work to be the only links missing in the chain of evidence upon which hinges the success or failure of the mine.

It thus happens that the resident mining engineer who remains upon the ground, who sees the mine opened and follows from day to day its history is the only man in possession of the real opportunity for continued observation and upon him rests a great responsibility, the responsibility of daily recording the data which are set before him. A few minutes only, spent *at the time* that new excavations are made, for a careful record of what has been seen may place in his hands needful information for which he must otherwise rely largely on his memory or on the verbal statements of others, to find in many cases that his reliance is ill justified by the accuracy of the information.

Even where the stress of practical work prevents a mining engineer from publishing the data which he has collected it may often be indirectly of great service to him. Professional geolo-

gists who write reports on mining districts, if dependent solely on their own observations, could rarely arrive at successful solutions of the problems involved if they did not benefit by the records of those on the scene of operation; they can themselves see but a part of the whole and the careful records of work as it is prosecuted from day to day are of inestimable value. This is even more true if the observations have been rendered available by being put in print. It cannot therefore be too often urged on engineers that they render to science that service, which they alone can render, of recording their observations on geological structure or geological features which will help to clear up complicated problems of ore genesis or geology—and publishing their results so that they may be rendered available to others.

THE PETROGRAPHY OF OPAQUE MINERALS.

Two papers appearing elsewhere in this issue by Dr. William Campbell on the microscopic investigation of opaque minerals and the application of the methods in the study of the silver bearing ores of the Cobalt Mining District are of somewhat unusual interest to students of economic geology. The value of these metallographic methods of study will be readily appreciated from the second of the two papers where the methods of research have been put to successful use in the determination of the mineralogy and genesis of the ores of the now widely known Cobalt mining region.

Mr. Campbell has opened up in his first paper a new field of microscopic research and has set forth in some detail the methods used in the studies which he himself has made. That others will follow exactly the lines of research and the methods which he has found most serviceable is hardly to be supposed, but that this careful work will bring within the field of observation and render clear some of the more obscure questions of ore genesis and the relation of ore minerals to one another, is unquestionable. It is now eighty years since William Nicol first prepared thin sections of rocks for microscopic purposes, and yet within this period the study of microscopic petrography has done a service

to geological science whose importance can even now hardly be adequately recognized. Before this means of observation was afforded to students of rocks only the more coarse-grained varieties of igneous rocks could be accurately determined and even these were in many cases but imperfectly understood. The number of unsolved geological questions intimately connected with the origin and character of unknown rock species was proportionately great. These conditions are entirely changed. There are few rocks which are not now susceptible to thorough mineralogical analysis and the difficulties which once attended our understanding of petrography have been almost completely removed.

It is not surprising that much petrographic literature was for many years largely descriptive, and that a great wealth of new names and subdivisions of more or less unimportant species should have been the first result of the opening up to possible observation of an immense amount of material not previously susceptible to study. Criticism has been justly directed of recent years against the unnecessary multiplication of papers on purely descriptive petrography. Many have asked, "to what use may this work be put in the solution of scientific problems?" Petrographers have now come to recognize that the microscopic study of rocks is rather a *means* than an *end,* that it is a science to be utilized for the solution of problems which could not otherwise be worked out, and that the multiplication of detailed descriptions of rock occurrences in no way unique nor of special importance only buries under a mass of unnecessary material investigations of real value in the solution of important problems.

It is probable that the study of opaque minerals by the microscope will be less in the nature of a descriptive science and more in the nature of a means for the solution of questions of paragenesis and of ore deposition, for they will naturally be chiefly applied to mineral occurrences whose commercial importance is the chief consideration.

Mr. Campbell has clearly shown that the methods first used in metallography can be applied to opaque minerals with very successful results, and that the order of origin of the several in-

gredients of ore deposits may be readily deciphered by means of such methods of examination. It is believed that these studies of opaque minerals will lead other students of ore deposits to work along similar lines and this class of research will do more to bring within the range of observation certain facts of mineral occurrence than any line of investigation that has been undertaken within recent years.

THREE IMPORTANT PUBLICATIONS.

Three publications recently received by ECONOMIC GEOLOGY are of such unusual importance to all who are in any way interested in applied geology, whether it be from a practical or scientific standpoint, that they seem to deserve more than the passing notice usually accorded to new books. These three publications will later be carefully and thoroughly reviewed in ECONOMIC GEOLOGY.

The first is the Geological Guide of Mexico (Guide Geologique au Mexique), recently issued by the International Geological Congress, which convened in the City of Mexico during the month of September. Mexico has, during the last decade, become the seat of such extensive mining operations that even the most meagre geological information is eagerly welcomed by all geologists and mining engineers, and a publication so thoroughly and carefully prepared as this geological guide must be at once recognized as having an unusual scientific and practical value. The guide is written in French in a clear and readable style and is remarkable for its typography and the beauty of its illustrations. It consists of separate pamphlets of an average length of twenty-six pages giving geological sections, maps, etc., of all of the important mining districts and noteworthy geological features of the various regions covered by the excursions made by the Geological Congress. Certain of the papers on economic geology furnish the only available information on more than one district of widely recognized commercial importance. The editors of ECONOMIC GEOLOGY hope, with the permission of the Committee of the Geological Congress, to publish in future issues translations

of a number of the more important pamphlets. Mexico is to be congratulated on having placed in the hands of professional men information so long desired on mining districts whose remote and unknown geological character has in no small measure handicapped successful mining in the regions concerned.

The second publication which accompanies the geological guide is of scarcely less importance and value to students of geology. It consists of a geological map of the continent of North America, including Canada, Mexico, the Central American states, Cuba, Alaska, Greenland, Iceland, and certain portions of the Arctic regions. The map was compiled by Mr. Baily Willis of the United States Geological Survey for the Geological Congress, with the coöperation of the Canadian and Mexican geological surveys. It is accompanied by a brief explanatory text of twelve pages. The scale is 1 : 5,000,000, and the map as a whole is about eight feet square, consisting of four sheets. Nothing so comprehensive has ever appeared in the way of geological mapping and the usefulness of the map can hardly be overestimated. A careful review will be published in a later issue of ECONOMIC GEOLOGY.

The third publication is the new bulletin, "Contributions to Economic Geology for 1905" (Bulletin No. 285), just issued by the United States Geological Survey. This comprehensive work includes a series of papers on districts of economic importance throughout the United States, and is a brief, tersely written encyclopedia of the most recent scientific investigations on economic deposits of all kinds. It is illustrated by line maps, and in the variety of deposits and material discussed is more complete and thorough than any of the three similar bulletins that have been published by the Survey.

There has been nothing undertaken by the Federal Survey in recent years in the interests of applied geology that can be regarded as having greater importance than these timely synopses of the most recent investigations on economic geology. The articles are usually written by men well versed in the subject, they can be read in a few moments by busy men occupied with practical matters, and serve to avert much of the adverse criti-

cism incurred by authors of more detailed geological reports on account of the delay which must always be inseparable from the preparation of elaborate scientific work.

Mining is now conducted so rapidly that detailed geological work not infrequently appears only after the virtual exhaustion of many of the deposits concerning which reports are written.

This annual bulletin of the Survey serves to place in the hands of operators all available information as soon as it has been obtained.

THE INDEX to the first volume of ECONOMIC GEOLOGY, numbers 1 to 8, inclusive, will be issued with the first number of the second volume. It will be so bound as to be easily separated from the other material of the issue.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, South Bethlehem, Penna. The full name of the author should be attached to all communications.

DO THE GEOLOGICAL RELATIONS OF ORE DEPOSITS JUSTIFY THE RETENTION OF THE LAW OF THE APEX?

Sir:—In any discussion of the law of the apex it must not be overlooked that we stand committed as a nation to the principle of extra-lateral rights, and that the mineral industry in the western states for forty years has been developed in conformity therewith. Every western mining district has become adjusted to the conditions arising from a legal recognition of such rights, and a return to the common law idea of possessory rights in real property, with its limitation to vertical planes projected downward from the superficial boundaries, would entail very serious difficulties.

Questions of geology did not enter into the congressional discussions of the mining bills when they were presented, and at the time when these were enacted into law such discussions would not have yielded permanently valuable fruits. The conceptions of the nature of ore deposits now held by geologists cannot in any large degree be said to equal in antiquity the law under which the mining industry in the western states exists.

Up to the passage of the Act of July 26, 1866, no title could be obtained to any mines of gold and silver discovered on the public domain of the United States. These metals were then still held

to be inalienable from the State, following the ancient theory of the right of the sovereign to the noble metals. Mining rights were essentially leaseholds from the government, and a distinction between ordinary holdings of real estate in fee simple, subject to taxation on an appraised valuation, and the rights which one might acquire in mining claims, still dominated the mind of Senator Sherman when he introduced Senate Bill No. 257, on April 9, 1866, with the avowed object of a final disposal by the United States of its proprietary title to gold and silver mines. (See speech of Senator Sherman on this bill, June 18, 1866, Cong. Globe, First Sess., 39th Cong., p. 3236.) It was then proposed to levy a special tax of 3 per cent. upon the output of all mines as a means of helping to pay the national debt, and it was only through the efforts of western congressmen and senators that the law then passed did not impose a tax of 5 per cent. upon the output. The bill was in its inception largely a fiscal measure, coupled with a sincere desire to improve the condition and opportunities of the miners, particularly through the conversion of mining rights into real property capable of valid conveyance on a par with other real estate.

The original bill, as drawn by Senator Sherman, was revamped in committee and issued a much more practical instrument than would have resulted but for the efforts of Senators Conness of California and Stewart of Nevada. These men were following the experience and conceptions of miners of the west, which were naturally crude, but superior to the ideas of the Senator from Ohio, whose knowledge of finance was sounder than his understanding of geology. Senator Stewart's contribution to what passed for technical elucidation of the bill was summed up in his statement in debate that "a vein pitches into a hill, and a perpendicular line would cut it up into pieces. This bill provides for selling the vein, following it into the earth, with its natural angles and dips." (Cong. Globe, First Sess., 39th Cong., p. 3452.) The only additional attempt at a geological contribution to the debate was a letter from an un-named mining operator, introduced by Senator Williams of Oregon, which demonstrates how little congressional discussion of the technical ques-

tions involved was able to advance a realization of the truth as we now comprehend it concerning metalliferous veins. In part, this letter declares, "experience all over the world shows a very uniform law that where true fissure veins have been discovered they may be relied upon for a gradual increase in width and richness to the greatest depth possible for the miner to obtain . . . Gold and silver quartz lodes are not like iron, or coal, or galena, or copper mines. They are generally found in narrow veins of one foot to five or seven feet in thickness, sometimes, though rarely, extending to fifteen or twenty feet. These stand often perpendicular, and sometimes with a slight dip or angle in the mountain. To measure and make sale of these by rods and acres upon the surface would be like measuring a string by square rule, or by determining the length and height of a party wall by cube measurement."

So uncertain was Congress upon technical questions that great latitude was allowed to local regulations of the miners in mining districts in the manner of locating and defining their claims, although onerous burdens were imposed in regard to the recording of claims, attestation by witnesses, and lengthy periods of publication of notices prior to the granting of title. But the law of 1866, regardless of deficiency in geological information, adhered fundamentally to the idea that a vein must be a well defined sheet between clearly recognizable bounding walls, and that the thing to which the miner must necessarily desire title was the vein, with slight consideration of surface rights. This idea was affirmed explicitly and repeatedly by decisions of the courts in cases arising under this act. Furthermore the principle of extra-lateral rights was stated in the most unequivocal terms, the text of the law on this point affirming the privilege of the discoverer of a vein "to enter such tract, and receive a patent therefor, granting such mine, together with the right to follow said vein or lode, with its dips, angles, and variations, to any depth, although it may enter the land adjoining, which land adjoining shall be sold subject to this condition."

Thus was error laid in the foundation of the legal structure, not through intent to do mischief, but from ignorance, for which

there were palliating excuses, and from the influence upon the minds of the legislators of a conception, almost as ancient as nations and governments, that gold and silver were things pertaining to a province apart from the ordinary concerns of men, to which the common rules of possessory right did not apply. The glamor and mystery of mining and of the manner of occurrence of veins unsettled the sound practical sense of men who could deal wisely with other affairs which they more perfectly comprehended.

The law of the apex was a sort of grouting poured in later to strengthen the weakness of the foundation, without remodelling its lines. The first use of this term was in Senate Bill 1103, introduced into the Third Sess. of the 41st Congress by Senator William M. Stewart on December 9, 1870. This bill was laid over by the House, but practically the same bill, containing the same terms, "top or apex," was presented at the next session of Congress by Representative Aaron A. Sargent, a lawyer of Nevada City, California, which, after amendment in the Senate, became enacted into law on May 10, 1872. The object of this act was ostensibly to remove many of the burdens of routine in acquiring claims which weighed heavily upon miners under the law of 1866, and to define more clearly the surface rights which should accompany a claim to a lode or vein. Very curiously, no explanation of the terms "top or apex" was given in debate, nor were they so much as mentioned. The purpose of the words, however, is easy to deduce from the difficulties arising under the law of 1866, where no limitations by end lines were imposed, and the right to follow the vein with its angles, dips and *variations* had led to serious conflicts. The law of the apex, accordingly, combined as it was with a restriction within imaginary bounding terminal planes, marked a distinct advance in determining the rights of locators of claims, modifying in important particulars the evils resulting from a departure from the common law idea of real estate tenure in conceding extra-lateral rights to owners of mining claims.

The quarrel, then, cannot be so much with the so-called law of the apex as with the law of extra-lateral rights. The mean-

ing of the word apex is now no longer a matter for discussion. It is not what we may choose to define it, but what the courts have declared it to be, and this is perhaps most clearly stated in the charge to the jury by Judge Hallett in the case of Iron Silver Mining Co. *v.* Murphy (1 Morr. Min. Rep. 548), representing an epitome of previous judicial decisions, as follows: "The top or apex is the end, or edge, or terminal point of the lode nearest to the surface of the earth. It is not required that it shall be on, or near, or within any given distance of the surface. If found at any depth, and the locator can define on the surface the area which will enclose it, the lode may be held by such location."

It becomes, then, a mere matter of fact whether such an apex does exist within the boundaries of a claim, which fact is usually capable of determination within reasonable limits of certainty. If the law of extra-lateral rights were repealed, the law of the apex, as a mere limitation thereof, would disappear also.

If metalliferous veins did actually exist, with well-defined bounding walls, as simple sheets of lode-matter held in the earth as the ham is held in a sandwich, the injustice of the departure made by Congress from the old ideas of rights in real estate extending toward the center of the earth within vertical bounding planes, would not be so apparent. In many respects it would add to the convenience and economy of mining operations, as our law-makers anticipated when the bill was passed. But the facts of experience fail utterly to confirm this simple assumption of the habits of veins. Although repeated court decisions have declared that the law has nothing to do with the genesis of veins, a proper conception of their peculiarities involves a consideration of origin, which must be taken into account in framing legislation, even if the adjudication of controversy may be affected solely by the state in which individual ore deposits are found to exist. For example, we know that many veins have been formed along planes or zones of faulting, and it is a common experience to find that such fractures may be confined to fairly simple, well-defined planes at considerable depths, where the great pressure prevented complicated fractures, whereas toward the surface the lessened resistance from pressure permitted exceedingly compli-

cated fracturing, resulting in the production of numerous branches, or a reticulation of fractures, along many or all of which metalliferous minerals in valuable quantity may have been deposited. It is manifestly impossible to decide in many such cases which is the main vein and which the branch. There is often no geological preëminence discoverable. Priority of location would determine ownership, but there may be opportunity for conflict on this point.

Again, veins frequently occur in rocks which have not been subjected to faulting or fissuring, the deposits occupying lines or zones favorable for the formation of ores owing to original peculiarities of physical structure or chemical composition in the parent rock, and such deposits are subject to extreme vagaries in shape and position, and may exist in the form of a complicated net-work, so that no single simple vein can be determined. An equally difficult case is presented in those deposits commonly known as masses, which bear no semblance to a vein within the meaning contemplated by the law of 1872. Being of irregular form, sometimes with equal extension in their two horizontal dimensions, with no single top or apex, and no ascertainable dip, except for some imaginary axis whose position cannot be known in advance of complete exploration of the deposit underground, every condition is absent for granting rights under the law to claimants with adjoining side lines which would admit of determining extra-lateral rights that would not be in violent conflict with the limited geological conception upon which such rights could be conceded.

The faulting of old veins by cross-fissures, with the subsequent mineralization of the new zone of fissuring, is another fertile source of confusion and conflict.

The congressional conception of a vein in the days when the laws of 1866 and 1872 were passed involved as an essential condition the existence of bounding walls. Thus and thus only could a vein be certainly followed "with its dips, angles, and variations" beyond the superficial boundaries of a claim. Veins do sometimes possess walls. In fact, an engineer of wide experience must admit that they usually do. That has nothing to do

with the genesis of walls, for the existence of bounding walls as a condition precedent to the formation of veins cannot be granted except as a merely occasional circumstance. The "wall," as a recognizable parting plane between vein and "country rock," is more apt to be an after effect from chemical action, kaolinization, sericitization, and often from subsequent faulting along planes parallel with the inclined axis of the lode. But in a great many cases no "wall," as a continuous phenomenon throughout the extent of the vein, can be definitely recognized, and this is particularly true of those veins which by their great size and high commercial value have become the basis for the largest permanent mining industries. Thus the law fails precisely where protection to the most extensive interests is at stake, because in form and character, and from the absence of clearly bounding walls, our greatest veins do not in a large majority of cases conform to the geological prescription of the law-makers. Occasionally we do find a great vein serving as a beautiful type of what Senator Stewart had in mind, as, for example, the Smuggler-Union vein near Telluride, Colorado, but how much more often do we find irregular ore masses, such as the familiar example of the Copper Queen in Arizona, among copper mines, and the Yellow Aster deposit in California, among gold mines!

Congress had no corps of geologists with whom to advise in 1866, nor even in 1872, although by the latter date they had discovered Dr. Raymond and Clarence King, but the Geological Survey was not established until 1879, and legislation was subject to the controlling influence of the untrained and half-informed theorist (an abundant class among so-called "practical miners"), more than of the trained and experienced mining engineer.

It is hardly to be doubted that the unwisdom of the law of extra-lateral rights has been borne in with convincing force upon the minds of our best informed congressmen, so that remedial legislation might be obtained, if a way could be shown whereby the reform might be accomplished without embarrassment to immense vested interests, based upon anticipations of resources secured to them under the old law. The owners of those close-packed

phalanxes of mining claims surrounding all great mines, sometimes honest men, but quite likely to be rascals holding on in the belief that the chief operators must eventually pay their price, are in a position to profit unjustly to the serious injury of established enterprises by a sudden stripping off of the extra-lateral right, and this prohibits such a course absolutely, for no alternative of governmental indemnity on so vast a scale could be entertained. We have admitted the royal Spanish land grant into the southwest, an exotic among the rank and file of holdings under United States patents, and so we would be obliged to nestle a brood of titles carrying extra-lateral rights abhorrent to the geological mind, hatched from the eggs of misunderstanding, in order to straighten out the course of future mining rights. It is difficult to see how the old established mining camps can be brought under a new law denying the extra-lateral right. But because a law framed in error as to the actual nature of veins, and conceding unjustifiable rights which work serious hardship, has also become the safeguard of immense vested interests, is no reason why the error should be perpetuated in relation to those mines which yet remain to be found. Because such camps as Butte and Bisbee and Bingham are so very great, is no reason why other greater ones may not exist in future where no mineral deposits are known to-day, and it is unnecessary to afflict these future camps with such disastrous legal warfare as has waged in almost every important western mining district over questions arising under the law of the apex and extra-lateral rights.

Yet the difficulty and delicacy of the task which would confront Congress in its efforts to improve the legislation affecting mines discovered on the public domain, may not be minimized, and account must also be taken of the powerful interests which justly would jealously watch and seek to guide legislation in order that they might not be sacrificed in a movement for reform.

The reform is needed, and it will become more difficult to effect with each year that it is postponed. It would seem that the American Congress of Mining has made a very proper move in this matter by preparing, through a committee appointed for this purpose, the draft of a bill designed to achieve the end

in view. After a wholesome demolition of parts of such a bill in congressional debate (for it should in no sense be, nor be permitted to become, a party measure to be passed in caucus and confirmed perfunctorily on the floor), our law-makers, and mine operators, and mining engineers may discover how to effectively coöperate in the production of a sound and practical instrument fit for permanent enrollment among the statutes of an intelligent nation.

COURTENAY DEKALB.

LOS ANGELES, CAL.

Sir:—Extra-lateral rights, to the dip, bounded by the production of the planes passing through the end lines, together with a claim *1500 ft.* long by *600 ft.* wide, existed in British Columbia, at least as far back as 1884—which was prior to any productive lode mining—and continued until April 23rd, 1892, when it was repealed and a rectangular claim *1500 ft.* by *1500 ft.* was substituted therefor with rights only within four vertical planes through the four sides.

This Act of 1892, of course, did not invalidate any rights acquired prior to its passage.

These "old style claims" have proved a fruitful source of litigation and some important suits are still pending. With the vertical lines there can be no dispute except as to accuracy of survey, with occasional disputes as to identity and location of record posts, which troubles are incident to any style of location.

In making the change from 600 to 1500 ft. wide, it was intended, by the extra width given, to about compensate the miner for the loss of the extra-lateral rights.

I have been all over British Columbia and have probably come in contact with a greater number of mining men, both operators, miners and prospectors, than any one else and I have only found one man who even suggested a preference for the *"extra-lateral rights"* system.

This gentleman lived the greater part of his life in California and is by profession a hydraulic placer miner, to which branch alone he has confined his attention in British Columbia.

This public endorsement of the vertical boundaries system is

the more emphatic, inasmuch as a majority of our mining men are from the United States, or have had their experience there; they came with pre-conceived ideas and have been converted.

The public in British Columbia is firmly fixed in its adherence to this principle.

Personally, from the standpoint of a disinterested observer, obliged officially to observe, I have not the slightest hesitancy in endorsing most emphatically vertical lines, in preference to extra-lateral rights—as giving a more secure title—freedom from litigation and the doing away with the crushing, through weight of expensive litigation, of the poor by the richer individuals or corporations.

WILLIAM F. ROBERTSON,
Provincial Mineralogist.

REVIEWS

The Geology of the Granby Area. By E. R. Buckley and H. A. Buehler. Vol. IV., 2d ser., Missouri Bureau of Geology and Mines, 1906.

The detailed study and mapping of the Granby area by Buckley and Buehler have yielded conclusions of more than local significance in the interpretation of the history of the development of the lead and zinc ores of the Mississippi Valley.

The Granby district lies some twenty-five miles to the southeast of the Joplin district in southwestern Missouri. The country rock is Mississippian limestone, 260 to 380 feet thick, unconformably overlain by Pennsylvanian conglomerate (Granby conglomerate), shale and sandstone, occurring in small isolated patches usually following topographic depressions in the Mississippian limestone. The ores now mined are chiefly blende, formerly chiefly calamine and galena. They are found in the Granby conglomerate and in the immediately underlying parts of the Mississippian; in other words, usually within or adjacent to depressions in the pre-Pennsylvanian topography. The ores are in "runs" with a comparatively great depth as compared with width, though the depth is not more than 215 feet and is for the most part less than 150 feet. Within a run are several openings separated by beds of flint from three to twenty feet thick. Near the surface there is the usual oxidized zone.

Concerning the origin of the ores it is concluded: (1) that the ore bodies have been the result of concentration through a process of solution and re-deposition brought about by downward circulating water; this process may have been interrupted by changes in the elevation of the land as a result of cycles of base-leveling; (2) that the original source of the metallic minerals has been chiefly the Pennsylvanian shales, sandstones and

limestones; (3) that the agent of solution and transportation has been meteoric water; and (4) that solution and deposition were dependent mainly upon the composition of this water and the nature of the rock through which it might be passing. This statement of conclusions is somewhat amplified below.

The downward circulation involves lateral secretion. The waters are partly oxidizing and carry the metallic salts, and are partly reducing and alkaline, the convergence of waters resulting in the precipitation of the ores. The same waters which are doing the work of the oxidized zone above are depositing metallic sulphides below.

The source of the ore and the associated dolomite, calcite, silica and pyrite is the Pennsylvanian which has been eroded. The presence of organic matter in the Pennsylvanian is believed to indicate favorable conditions for the precipitation of lead and zinc during the Pennsylvanian sedimentation. The ultimate source of materials for this sedimentation may have been the Cambro-Silurian and crystalline rocks. It is thought that the ores were originally precipitated near the Pennsylvanian shore.

Earlier and later periods of concentration are distinguished in the ore deposits, all of them, however, being the result of downward moving waters. It is noticeable that the removal of the sulphides, carbonates and silicates from the zone of weathering to deeper levels has in many places lagged behind the surface weathering. Especially is this true of the galena and carbonate minerals, which in the Granby area have been found in their greatest richness near the surface, often at the "grass roots." At least three-fourths of the galena mined has been obtained within 60 to 70 feet of the surface. This condition may be due in part to the greater stability of the lead ores within the zone of weathering, but mainly to the fact that it was the chief horizon of the early concentration of the galena from the convergent downward circulation.

Considerable space is given to pointing out the differences between the conclusions reached and those of other workers in the Mississippi Valley, especially Van Hise and Bain, who hold that the Missouri ores have undergone two concentrations, the

first by artesian waters circulating through the Cambro-Silurian and coming to the surface through fault and joint planes intersecting the Devono-Carboniferous shale and Mississippian, depositing the ores in part under the reducing influence of organic material from the Devono-Carboniferous; the second concentration due to downward moving meteoric waters directly from the surface. The source of the ore in this case would be principally from the erosion edges of the Cambro-Silurian or the immediately adjacent crystallines.

That the concentration of the ores has occurred under continuous downward circulation, collecting its salts from the Pennsylvanian above, instead of partly during an upward circulation collecting its salts from the Cambro-Silurian below, is believed by Buckley and Buehler to be brought out by the following facts: (1) The greater abundance of lead, zinc and iron salts in the overlying Pennsylvanian than in the underlying Cambro-Silurian, due to precipitation by the abundant organic material of the Pennsylvanian during its sedimentation. (2) In certain parts of the state the occurrence of zinc ores in pockets with coal where it could not have been deposited from below but must have come from the Pennsylvanian above. (3) The fact that all of the salts in the overlying rocks which had been eroded would be contributed, while only a very minute part of those in the underlying rocks would be available. (4) The Pennsylvanian furnishes an adequate source of the dolomite which had been thought necessarily to have come from the underlying Cambro-Silurian. (5) The streams from the highlands entered the Pennsylvanian ocean at irregular intervals and deposited their salts close to the shore, thus explaining the present local distribution. (6) The faults supposed to furnish the egress for the deep circulation are found not to be sufficiently extensive for this purpose, the irregularities in surface distribution which had been taken as evidence of faulting being due to unconformity of the Mississippian upon the Pennsylvanian, and the supposed fault breccias near the contact being really basal conglomerates of the Pennsylvanian or solution breccias. (7) The mine waters now depositing ores fluctuate in abundance with the seasonal rainfall,

indicating their derivation directly from the surface rather than from an artesian circulation, which would be constant. (8) Analyses of the deep artesian waters from the Cambro-Silurian yield little or no lead and zinc, while such are abundant in the mine waters supposedly from the surface. (9) If the ascending waters were neutral or alkaline, the salts of lead, zinc and iron would be thrown down in intimate association. If the waters were acid, the galena would be thrown down first; that is, below, and the zinc and iron salts carried farther and deposited above. The present distribution is the reverse of this, the galena being above and the iron below. While this reversal may be due to later concentration by waters directly from the surface, it is thought, on the basis of the quantitative relations of the lead, zinc and iron, that this would involve a greater erosion of the Mississippian and secondary concentration than there is evidence for.

The evidence and arguments presented by Buckley and Buehler undoubtedly favor the conclusion that the Granby ores are derived from the Pennsylvanian formation. To a striking degree the conclusions resemble those of Chamberlin for Wisconsin in the emphasis on downward moving waters as the agents of transportation. Nevertheless, the alternative hypothesis of the derivation of the ores from the Cambro-Silurian is still favored for southwestern Missouri in general by Van Hise and Bain, whose field work, principally the latter's, was largely in parts of southwestern Missouri outside of the Granby district. In this connection it may be pointed out that some of the arguments presented for the derivation of the ores from the Pennsylvanian do not, in the reviewer's opinion, entirely exclude the alternative hypothesis—the primary derivation of the ores from the Cambro-Silurian. For instance: (1) It is argued that the waters could not come from below because faults are not as important as previously thought to be, though both faults and joints are present. Further evidence is needed to show that there may not still be sufficient fracturing to afford channels or escape for deep flowing waters; (2) the argument that the mine waters fluctuate with the seasonal precipitation does not necessarily show that part of the

waters may not come from the artesian circulation. If the artesian circulation is constant in amount, then variation in the total amount with the seasons is to be expected. (3) The conclusion that the original (authigenetic) disseminated ores are more abundant in the Pennsylvanian than in the Cambro-Silurian and that the widely distributed ores of the Cambro-Silurian are really themselves secondary is based on the belief that the conditions for the original precipitation of ore were theoretically more favorable during the deposition of the Pennsylvanian than of the Cambro-Silurian, for it is obviously difficult to show by observation that the ores in the one case are secondary and in the other case original. In arguing a theoretical probability a large number of factors must be taken into account which render the conclusion anything but certain. It might be noted, for instance, that the lead and zinc salts of the Cambro-Silurian are associated with chemical sediments, limestone, while in the Pennsylvanian they are associated with mechanical sediments; that the former conditions may have been more favorable for transportation to the sea than the latter; that the association with organic material in the Pennsylvanian may account for precipitation and not for transportation. (4) If the ores are derived from the Pennsylvanian during its erosion, ores should be abundantly found near the surface in parts of the Pennsylvanian only partially eroded. (5) The greater abundance of lead and zinc salts in mine waters than in deep-flowing waters is to be expected under any conditions. (6) Whether the waters are acid, alkaline or neutral is still to be proved. Buckley and Buehler believe, largely from theoretical considerations, that the waters contain acid sulphates, and therefore conclude that the present vertical order of the ores could not be explained as a result of deposition by upward moving solutions except as modified by a later downward concentration, which they do not think has been sufficiently effective to accomplish this result. Van Hise and Bain believe that in general the waters are alkaline and neutral and therefore such as to explain the present vertical concentration by an upward circulation modified by a later downward concentration.

Aside from the conclusion as to the source of the ores, the differences between the conclusions of Buckley and Buehler and those of Van Hise and Bain are not as fundamental as would be indicated by the emphasis on contrasting terms "upward concentration" and "downward concentration." Under either theory the conditions of solution and transportation of the ores are much the same, solution goes on largely during the downward movement in both cases, there is in each case a much larger lateral movement than either upward or downward, the conditions of precipitation are the same in both cases, and in both cases there are two or more concentrations, whether these be called first and second, or earlier and later.

The report as a whole, while somewhat controversial in its tone, is a valuable and most significant contribution to the discussion of the genesis of the lead and zinc ores of the Mississippi Valley. Geologists will look with much interest for the results of the authors' further work in the Missouri districts.

C. K. LEITH.

Geological Map of Illinois, The. By STUART WELLER. Bulletin No. 1, State Geological Survey, Urbana, 1906.

The recently organized geological survey of Illinois has early exhibited a commendable activity by issuing three bulletins.

The first of these bulletins contains a geological map of the state with a brief explanatory text setting forth the sources from which the information was derived and giving a short discussion of the various formations exposed in the state.

As stated in the prefatory note by the director the map is a compilation and not the result of original work—the object of the Survey officials being to place in the hands of the public as soon as possible such information as had already been accumulated both by previous state surveys and other investigations. The map therefore cannot be as searchingly criticised as those which are from time to time to follow it when more extensive original work has been accomplished.

The map is compiled from a number of sources. The old map of the Worthen Survey in 1876 is the chief source and like many

of the early state surveys it is quite lacking in the detail of the more careful work which will be carried on in future. Other sources are a map published in the seventeenth annual report of the U. S. Geological Survey by Frank Leverett, published work and field work of J. A. Udden, O. H. Hershey and George Matson and a detailed map of a small area published by the U. S. Geological Survey in connection with the investigations on the zinc and lead deposits of the Mississippi Valley.

The map thus varies in accuracy in different portions according to the relative accuracy of the different sources.

The map is on a scale of twelve miles to the inch—a scale which materially decreases its usefulness for economic purposes but is probably as large as the accuracy of the original sources would permit. Coal mines are indicated by red crosses, their locations having been determined from the Peabody atlas.

A legend accompanies the map showing the formations depicted and having on one side a description of the lithological character of the several members and at the other a description of the more salient features of the economic products occurring in those members. The latter feature seems to emphasize the economic purpose of this work which is further evident through all of the discussions in the text and also in the Director's preface. Five geological periods are represented: Ordovician, Silurian, Devonian, Carboniferous and Tertiary, and of these the Ordovician and Carboniferous are sub-divided into four and three sub-divisions respectively, a degree of detail which would hardly seem warranted by the accuracy of the information were it not for the confessed preliminary nature of the work.

Three columnar sections appear on the left-hand edge of the map, one representing the formations in northern Illinois, another those in central Illinois and the third those in southern Illinois.

The Survey of Illinois has followed the custom of the United States Geological Survey in the choice of colors to represent formations and in the system by which one color is made to serve for several different formations, the areas being distinguished by different symbols. It has also followed the plan of repre-

senting the subordinate divisions of one geological age by shades of the same color. Thus the Carboniferous is represented in blue, the coal measures by light shades and the Mississippian by a darker shade of the same color. This would seem to the writer to be the inauguration of an unfortunate custom, one which might in some measure have impaired the value of the otherwise truly admirable folio atlases of the United States Geological Survey if separate economic maps were not published together with those representing the areal geology. The Illinois Survey is publishing but a single map and it should for this reason be made as serviceable as possible.

A geological map is designed to represent the *outlines* of the several formations and this can be accomplished only by a marked contrast between adjoining and differently colored areas. The sub-divisions of the Carboniferous if represented by shades of a single color blend into one another so that the line of demarcation cannot be seen and it is often only by running over the whole map with a pencil along a faint and indistinguishable line that areas of a single sub-division may be made out. And yet it is the *sub-divisions* that are especially important as they are frequently made on economic grounds. Thus it is not the line of demarcation between the Devonian and the Carboniferous that is important to a coal operator—it is the line between the sub-divisions of the Carboniferous, between the area of thick workable coals and that of thin unworkable coals and yet this is exactly the boundary that is so indistinct as to be practically invisible. Adjoining areas should be represented by strongly contrasted colors and especially so where the boundary has a marked economic significance. This custom of coloring sub-divisions of a single formation in shades of the same color would seem to have arisen from a desire for system and unity, to which other conditions were apparently rendered subservient.

Let the Illinois Geological Survey exhibit its independence and break away from a custom that, in the opinion of the reviewer, is detrimental to the economic interests of geological mapping.

J. D. IRVING.

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SCIENTIFIC NOTES AND NEWS[1]

THE TENTH INTERNATIONAL GEOLOGICAL CONGRESS.

The convening of the Tenth International Geological Congress under the auspices of the Mexican Geological Survey in the City of Mexico during the months of September and October just passed is an event of great importance to geologists and mining engineers, not only on account of the interesting and valuable papers which were there presented, but on account of the interest in scientific questions which has been aroused by the presentation of the results of research and the collaboration of men interested in similar lines of work. It is probable that most conventions, and particularly those designed for scientific purposes, have a value for the furtherance of research which is somewhat disproportionate to the results as expressed in the published records of their deliberations. Men who attend such conventions do not do so simply for the purpose of hearing formal readings of papers presented by the attending members. They go for the purpose of discussing informally with other men occupied with similar work such questions as may be brought up on the subject in which they are interested—to talk with those holding different views, to learn so far as possible to appreciate the reasons which have caused differences of opinion, to carry away with them broader, more liberal views and gain a closer approach to scientific truth than can be done in any other way.

The sessions of the Congress held in the City of Mexico were from the sixth to the fourteenth of September, inclusive.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

The Mexican Committee on Organization, with the assistance and encouragement of the Mexican government, had made very complete arrangements for the sessions and excursions, and the Geological Institute of Mexico provided meeting rooms and an assembly room fitted with a Bureau of Information and a telegraph, cable and post-office.

The Council of the Congress met on the sixth of September at 8:30, formally approved the program provided by the Committee on Organization, and elected officers for the Tenth Congress. The new officers chosen were: President, Don José G. Aguilera, Director of Geological Institute of Mexico; secretary-general, Don Ezequiel Ordoñez, sub-director of the Institute; vice-presidents from each nationality represented, and several assistant secretaries. These officers constituted the Council of the Tenth Congress and will elect their successors at the Eleventh Congress to be held in Stockholm in 1909 or 1910.

The sessions were formally opened in the historic building of the National School of Mines by His Excellency, General D. Porfirio Diaz, President of the Republic, under whose high patronage the Congress was held. This was a most solemn and noteworthy occasion and the local papers later referred to the gathering present as one of the most distinguished ever assembled in the Republic of Mexico.

Following the opening the general sessions were instituted and continued through the week, interrupted only by short excursions to the great lava flow of Qedocoal, south of the city, to the historic city of Cuernavaca, and to the famous silver mines of Pachuca. Among the most interesting and important of the papers presented were those of the two sessions of Monday, September tenth, which day was devoted to economic geology. These included papers upon the following subjects: "Some Relations of Palaeogeography to Ore Deposition in the Mississippi Valley," by H. Foster Bain; "The Distribution and Origin of the Gold Placers of Alaska," by A. Brooks; "Upon the Relations between the Propylitic State (Greenstone) of Andesites and the Genesis of Veins within this Rock," by B. von Inkey; "Ore deposits at the Contacts of Intrusive Rocks and

Limestones and Their Significance as regards the general Formation of Veins," by J. F. Kemp; "Upon the Genesis of the Metals of Aluminium of Bihar," by J. Szádezcky; "Upon the Filling of Some Metalliferous Veins," by J. D. Villarello; and finally a very important contribution upon the "Origin and Classification of Ore Deposits," by W. H. Weed.

Preceding and following the sessions long excursions were given under the patronage of the government, the excursions to the north through the great mining districts of Mexico, being a particularly valuable trip. Every provision was made for the comfort of the guests of the Republic and the officers of the National Geological Institute were most efficient and courteous geological guides. They prepared and distributed to the visiting geologists a most comprehensive geological guide-book which added greatly to the information obtained under their personal guidance during the trips.

Among the many brilliant and magnificent receptions tendered the visitors was that given on the evening of September 12 by President and Mrs. Diaz at the historic Castle of Chapultepec. It was with most cordial appreciation of the greatness of the President and the graciousness of his most charming wife that the geologists voted this beautiful reception the most delightful evening of their stay in Mexico.

The *Prix Spendiaroff,* given every three years by M. Spendiaroff, of Russia, in memory of his son, a geologist, who lost his life in one of the excursions of the St. Petersburg meeting of the Congress, was this year awarded to Professor Th. Tschernyschew, Director of the Geological Survey of Russia, for his work entitled *Die Obercarbonischen Brachiopoden des Ural und des Timan.*

Among the names of the large number of members and delegates noted at the Tenth Geological Congress were: Adams, Dr. F.; Aguilar y Santillán, R.; Aguillera, Josê G.; Anderson, Tempest; Bain, H. Foster; Bascom, Miss Florence; Becker, Dr. G. F.; Bergeat, Dr. A.; Böse, Dr. Emilio; Bryant, H. G.; Cadell, H. M.; Chamberlain, Dr. T. C.; Cleland, H. F.; Coleman, A. P.; Credner, Professor Dr. H.; Danlos, J.; Darton, N. H.; David,

T. W. E.; Davis, W. M.; Diener, Dr. C.; Eckert, K.; Emmons, S. F.; Fairchild, H. S.; Frech, Dr. F.; Freudenberg, Dr. W.; Friedländer, Dr. E.; Grässner, P. A.; Günther, Dr. S.; Hackman, Dr. V.; Halet, I. E.; Hammer, Dr. W.; Hayes, C. W.; Heilprin, Professor A.; Hlswatsch, Dr. K.; Hobson, B.; Hovey, Dr. E. O.; Iki, T.; Janischewsky, M. E.; Keilhack, Dr. K.; Kemp, Professor J. F.; Keyes, Dr. C. R.; Kümmel, H. B.; Lamothe, Gen. S.; Lawson, Professor A. C.; Leith, Dr. C. K.; Low, Dr. A. P.; Manson, Marsden; Matuschka, Dr. Graf. von; Miller, Professor A. M.; Miller, W. G.; Muñoz, R.; Ordóñez, E.; Osann, Dr. A.; Philippi, Dr. E.; Plagemann, Dr. A.; Reid, Professor H. F.; Richards, Dr. J. W.; Ries, Professor H.; Ross, Dr. H.; Rothpletz, Dr. A.; Sabatini, V.; Schenck, Dr. A.; Schmidt, Professor Dr. A.; Schuchert, Professor C.; Shepard, Professor E. M.; Sjögren, Dr. H.; Smith, Dr. W. O.; Stepanescu, Professor G.; Tietze, Dr. E.; Tschernyschew, Dr. T.; Wahl, Dr. W.; Weed, W. H.; Wolff, J. E.; and Woodward, Dr. J. B.

THE NINTH ANNUAL MEETING of the American Mining Congress held its first session in Denver, Colorado, on October 16. The session was largely attended by representatives of the western mining industry. An address of welcome was delivered by Governor McDonald of Colorado and Mayor Speer of Denver. Papers were read at the afternoon session held in the Broadway Theatre. Some important papers were those of Mr. E. W. Parker of the United States Geological Survey on the necessity of more vigorous action toward reducing the high accident rate characteristic of American coal mining; J. A. Holmes on the methods adopted by European governments in officially safeguarding the lives and health of mine workers; T. A. Rickard on the geological distribution of gold, and John Dern on the mineral resources of Utah.

At the evening session a discussion was opened by D. W. Brunton on mine drainage districts which was vigorously taken up and thoroughly discussed. It concerned the enactment of a law to ameliorate the somewhat varying practice of mine drainage.

It will be a source of some satisfaction to mining engineers to follow the deliberations of this Congress and note that there seems to be a firm resolve among the mining men of the country to advance the interests of mining and particularly to bring about the betterment of our federal and state laws.

It is now better understood than heretofore that the Mining Congress is not a body organized for the discussion of scientific questions—a fact which has not at all times been sufficiently clear to avert the feelings of disfavor with which the Congress and its work have been regarded in some quarters.

The aims of the Congress are largely of a political nature and the ends which it is hoped may be accomplished are well worthy of the careful consideration of mining engineers in all parts of the country. The defects of our federal and state mining laws are so glaring and their inapplicability to the conditions of nature and the interests of the mining public are now so apparent that no doubt exists as to the necessity for change. That such change can come only after persistent concerted action by men whose opinions are respected and will weigh with the general public cannot but be fully recognized. If the future meetings of the Congress will confine their attention, as has in this case been done to the amelioration of present conditions and will avoid the detailed discussion of scientific questions much may be accomplished. Such conventions as this are so often occupied largely in the determination of the place and date of the next meeting that frequently nothing is accomplished. Denver is to be congratulated on the effectiveness with which the work of the Congress has been done and mining engineers may now hope for some definite results as the outcome of future meetings.

ACCORDING to the Canadian Mining Review, Mr. D. D. Cairnes has reported the discovery of rich quartz lodes carrying free gold and sylvanite in the region about Lake Bennett in southern Yukon. The discovery was made by the geological survey party after diligent search and is one of the many instances in which the Canadian Geological Survey has taken an active part in the opening up and development of a new mining region. If the reports are not exaggerated the Lake Bennett district bids fair

to see deep mining carried on on an extensive scale in the near future.

THE ROYAL COMMISSIONER on Coal Supplies of Great Britain has issued a series of extremely valuable volumes containing an immense amount of information as to the available coal of the British Isles, its occurrence, estimated worth, quality, accessibility, etc. Some of these volumes will be later reviewed in ECONOMIC GEOLOGY and it is believed that they will be of unusual interest to those interested in the world's coal supply. They may be purchased of Wyman & Sons, Fetter Lane, London, E. C.

Mr. F. H. HATCH, formerly geologist for the Consolidated Gold Fields of South Africa, has removed to London and has now an office at Lewis & Marks, 37–39 Threadneedle House, Bishopgate Within, London.

SOME valuable deposits of copper ore have lately been discovered in the Whitehorse district of the Yukon Territory.

DURING THE SUMMER just passed the economic work of the United States Geological Survey has been carried on by the following parties:

Mr. F. L. Ransome has, late in the season, taken up the economic geology of the Tombstone district, Arizona.

Mr. L. C. Graton has investigated the effect of hydraulic mining and stream erosion in the Sacramento Valley.

Mr. Ralph Arnold has examined the oil fields of southern and central California.

Mr. H. S. Gale has studied the coal fields in Colorado on the White River, while Mr. Wm. K. Shaler has continued work in the Durango field.

Mr. A. Keith in November began geologic work on the Dahlonega quadrangle, Georgia.

Mr. W. H. Emmons is still at Phillipsburg, Montana, engaged in the study of the economic geology of that quadrangle.

Mr. A. J. Collier is engaged in an extensive geologic reconnaissance of the Colville Indian Reservation.

Mr. S. H. Ball is investigating the Hartville iron ores of Wyoming.

THE EXTENSIVE GEOLOGICAL WORK which is being conducted by the Canadian Geological Survey is rapidly bringing within the field of knowledge much of the great unexplored territory of the northern part of the continent of North America. A glance at the geological map of North America recently published by the International Geological Congress will show how much of this northern territory has been covered. Detailed work is progressing rapidly. The work of some of the members of the Survey may be of interest to our readers and is given below:

Mr. R. G. McConnell and Mr. J. Keele, with a large field party, have been engaged on the estimation of the amount and value of the high-level gold-bearing gravels of the Klondike and its tributaries.

Mr. D. D. Cairnes spent the past summer investigating the geology of the country near the British Columbia-Yukon boundary line where a number of important discoveries have been made of gold, silver and copper. The gold is found in long quartz reefs and frequently occurs in telluride ores.

Mr. W. Leach explored the Bulkley Valley on the upper part of the Skeena River through which the Grand Trunk Pacific Railway will pass. He traced and mapped the important coal and copper deposits of that district.

Mr. O. E. LeRoy was engaged upon a close examination of the geology of the British Columbia coast from the International Boundary northward to Howe Sound. He thinks highly of the large bodies of low grade copper on the mainland and Texada Island.

Mr. Charles Camsell initiated work upon a map sheet along the valley of the Similkameen River in southern British Columbia, starting from the International Boundary, and making important economic discoveries of great bodies of low grade copper ores.

Mr. R. W. Brock, assisted by Mr. G. A. Young and Mr. W. Boyd, was in charge of a large field party at Rossland, B. C. The exhaustive study of this area approaches completion and a report upon the work will be published, probably next spring. Great

benefit has already been derived by the miners from Mr. Brock's study of the ore-bodies.

Mr. D. B. Dowling, assisted by Mr. G. Malloch, has continued the mapping of the coal areas of the Cascade Range, and a result of this summer's work is the discovery of thick beds of excellent coal on the Brazeau and Saskatchewan rivers.

Mr. R. Chalmers was employed on an examination of the clay deposits of the new provinces of Saskatchewan and Alberta; he located a number of places for the manufacture of brick, firebrick and cement.

Mr. Theo. Denis investigated new discoveries of gas, oil and coal in the west in order to bring the data for his forthcoming report on fuels up to date.

To Mr. W. McInnes and Mr. O'Sullivan was assigned the work of exploring the country between Lake Winnepeg and Fort Churchill on Hudson Bay. A knowledge of this portion of the country is required for the new line of railway extending from the northwest plains to Hudson Bay, which is intended to take advantage of the short northern route to Europe via Hudson Strait.

Mr. W. H. Collins made an exploration of a belt of country about thirty miles wide and extending westward about one hundred miles from Lake Nipigon, along the line of the new Transcontinental Railway. He reports mineral-bearing rocks only in the western part of this region.

Dr. A. E. Barlow and party explored and mapped a considerable area east of Lake Timiskaming and, although some economic minerals were found, no trace was discovered of an extension of the rich silver-bearing ores found about Cobalt on the west side of the lake.

Mr. W. J. Wilson examined closely a belt of country one hundred miles long, extending eastward from Abitibi Lake to the Bell River. He reports that this region is almost wholly covered with a thick mantle of clay, the deep swamps being very difficult to traverse.

Mr. W. Johnston was employed upon the sheet maps of south-

ern Ontario and completed the surveys of the Peterborough and Prince Edward sheets.

Mr. E. D. Ingall spent part of the season on the copper deposits of Ontario and Quebec, with the object of writing a bulletin to appear shortly.

Dr. R. W. Ells, assisted by Mr. J. A. Robert, worked upon the rocks of southern New Brunswick with a view to the production of a sheet map of the environments of the city of St. John. He also visited many of the mines of the province in order to obtain information for a bulletin on the minerals of New Brunswick.

Mr. Hugh Fletcher and Mr. E. R. Faribault have been chiefly engaged in the revision of map sheets in Nova Scotia with a view to their early publication. Mr. Faribault has now completed his long study of the gold-bearing rocks of the province and during the coming winter will issue an exhaustive report and portfolio of maps upon this important subject.

THE IMPORTANCE of the impetus which has been given to prospecting and mining in Canada by the discovery and development of the Cobalt mining district may be recognized from the fact that during the months of April, May and June about fifty companies were formed with an aggregate capitalization of $32,000,000 to exploit the mineral resources of the new mining area.

A CIRCULAR written by Mr. S. F. Emmons and recently sent to the members of the U. S. Geological Survey engaged in economic work contains certain definitions for the guidance of authors in writing economic reports. It is expected that authors will use the terms defined with the meanings given. Some of the definitions are of sufficient interest to warrant repetition. These are:

Vein, lode, vein systems.—A vein is a single ore-bearing fissure, generally, though not necessarily, with one or two well-defined walls.

When several veins are so closely spaced that the ground between them becomes in places ore bearing and in its whole width constitutes an ore body, the assemblage is spoken of as a "lode."

"Vein system" may be used for a larger assemblage of vein fissures, which may include several lodes. Usage may vary somewhat in different districts, but the general order from simpler to more complicated fractures will be "vein," "lode," "vein system." The more subordinate fractures, such as little veins that cross the material included within vein walls, may be called "veinlets" or "stringers."

Shear zone.—It is well to avoid a too general use of the term "shear zone." In one sense any vein could be called a "shear zone," since its fissure was probably formed under some sort of shearing stress. On the other hand, "shear zone" is more properly a term belonging to general geology, used to define the zone along which the rocks have been sheeted or laminated by a shearing stress with some lateral movement, but which is by no means necessarily or even frequently mineralized. If the term is used to designate mineral-bearing fissures in general, this distinction is lost sight of. It is therefore advisable to restrict its use to deposits formed along geological shear zones where the resulting water channels were so irregular that they can not be defined under any of the preceding heads.

Sheeting or *sheeted zone* may be used in cases where the movement has resulted in parallel fissures that have left thin sheets of country rock between them.

Bedded vein.—As rock fractures are independent of and generally cut across the bedding, the alternative form of deposit, as contrasted with a vein deposit, is one that conforms with the bedding, and has hence been called a "bedded deposit." Among miners the term "blanket vein" is usually applied to any nearly flat deposit.

Gash vein is a term employed by Whitney to describe a vein that fills joints or fissures in limestone in the lead deposits of the Mississippi Valley region. It is a vein that does not extend beyond a given bed or similar rock mass.

True fissure vein.—This term was originally used by Whitney (Metallic Wealth of the United States) to describe a true vein as distinguished from a gash vein, the latter being limited in extent, whereas the former, according to him, "may be pre-

sumed to extend for an indefinite distance downward." From this statement apparently has sprung the idea common among miners that a true fissure vein is the most desirable form of mineral deposit, because of its indefinite extension. This is a popular delusion that it is not desirable to perpetuate; hence the use of the term should be avoided. "True vein" was the term in use before Whitney's publication, and among the earlier writers on ore deposition signified a vein deposit filling a fissure; hence the term "fissure vein" is in a strict sense pleonastic and should not be used in classification.

Some of the variations of the vein deposit are as follows:

Linked veins.—These are deposits filling approximately parallel and overlapping fissures, arranged en échelon, and connected or linked by small, irregular cross stringers. As the deposit pinches out on one fissure it is taken up on one of the overlapping fissures.

Stringer lode.—A lode made up of irregularly branching and anastomosing stringers or veinlets. The rock between the veinlets is frequently so much mineralized as to constitute ore, when the whole is worked as a single vein.

Chimney, stock.—"Chimney" is applied to ore bodies which have not the tabular form of a vein but are rudely circular or elliptical in outline horizontally and have a very considerable vertical extent. "Stock" is applied to a similar body of still greater irregularity of outline.

Ore shoot, pay shoot.[1]—An ore shoot is the richer portion of a deposit. A pay shoot is that which is rich enough to exploit. While its outlines are not generally well defined, one can usually determine that it has a longer axis which forms a large angle with the horizon. The inclination of this longer axis is called the "pitch" of the shoot, a term originally used to signify the inclination of the axis of a fold. It is not synonymous with "dip," though in a vein deposit the pitch necessarily partakes of the inclination of the vein or its dip. It has, however, a further inclination within the plane of that vein.

[1] Sometimes wrongly written "chute," which is a French word signifying fall and properly applicable only to the artificial passages through which ore falls to a lower level.

Contact deposits.—It is advisable to restrict the term "contact" veins or deposits, as has been suggested by Lindgren, to those which have been formed by contact-metamorphic agencies and which carry the minerals characteristic of such action. This use eliminates from this category many forms of deposit that are so termed simply because they happen to occur at the contact of two different kinds of rock without regard to their origin. Contact deposits, as thus restricted, occur mostly in limestone at or near its contact with an intrusive igneous rock.

Fahlband, segregated vein, impregnation.—As a general rule care should be taken to avoid using the name of a process as the definition of a type of deposit. A number of terms that are useful in descriptions can not for this or for some other reason properly be used in defining types of ore deposits. Such are "Fahlband," "segregated vein" or "segregation," and "impregnation."

"Fahlband" is a local Norwegian term not generally applicable nor easily defined. It was originally used by German miners to distinguish certain bands of schistose rocks which are impregnated with finely divided sulphides and not in themselves rich enough to work, but which were thought to have exerted an enriching influence on the veins that cross them.

The other two terms define processes that may take part in the formation of many different deposits, and hence can not properly be used to characterize a single type.

"Segregated vein" has been used, for instance, to define materials that have been concentrated in a given sedimentary bed. The term would be more appropriately used for the material gathered together from a molten magma. In either case, it is not sufficiently distinctive to be used to characterize any single type of deposits.

The term "impregnation" has been used by different writers in many and conflicting senses. It properly signifies the introduction of mineral substances in a finely disseminated condition into rocks, either as a filling of open spaces or as a replacement of certain minerals. To describe the occurrence of ore in small, irregular, disconnected patches throughout the mass of a rock

"dissemination" or "disseminated deposits" is a preferable term, since it has no genetic signification.

Metasomatism.—This may be defined as the process by which, through chemical interchange, a mineral or an aggregate of minerals undergoes partial or complete change in chemical constitution. The term "metasomatism" is of wider application than "pseudomorphism," in that it does not necessarily involve the preservation of the crystalline form of the original mineral. In large rock masses, as, for instance, in the metasomatic replacement of limestone by dolomite or by metallic sulphides, it often involves a change in volume, the resulting mass being more or less cavernous.

Replacement.—As a general term synonymous with "metasomatism," "replacement" is preferable to "substitution."

Alteration.—The term "alteration" applies to the partial change of substance in a rock or mineral which does not necessarily involve its replacement by another. It is a purely chemical process.

Decomposition.—This term signifies a dissolution of a rock or mineral into its component parts, which involves a physical as well as a chemical change. It occurs most commonly during the process of weathering.

Weathering.—The term "weathering" should be confined to changes in cohesion and composition of rocks near the surface that are due to the decomposing and oxidizing action of surface waters. Its tendency is to destroy the rock as a geological unit.

THE WORK OF the Illinois State Geological Survey on the coal fields of Illinois is going rapidly forward. A large number of mines already have been visited, and careful samples taken for laboratory study, one hundred and sixty such samples being now on hand. Director Bain has recently visited the Livingston and La Salle county fields, preparatory to making careful surveys. J. A. Udden is now engaged in working out the faults near Peoria which have been such a constant source of annoyance and expense to operators in that vicinity. T. E. Savage is making a detailed study of the Springfield mines. J. J. Rutledge

has taken up an investigation of the coals of the East St. Louis-Belleville area, and F. W. DeWolf is about to begin work in Saline and Gallatin counties. His work, as also that of David White, who is making collections of fossil plants throughout the field, is carried on by the U. S. Geological Survey in coöperation with that of the state. Topographic surveys preparatory to next season's work are being carried on near Harrisburg, Marion, Herrin, Murphysboro, Trenton, Edwardsville, Alton and Tallula. A preliminary report upon the composition and character of Illinois coals is in press.

DR. ANDREW FLEMING WEST, dean of the Graduate School of Princeton University and since 1883 professor of Latin, who was recently selected to succeed Dr. Pritchett as president of the Massachusetts Institute of Technology, has declined to accept the position.

IT IS STATED by the *Engineering and Mining Journal* that another vein of silver-bearing cobalt ore has been discovered by diamond drill prospecting under the waters of Clear Lake, west of Cobalt, Ontario. The discovery was made on the property of the Clear Lake Mining Company which owns the right to mine in the area covered by the lake.

IN AN ADDRESS before the recent State Development Convention at Winchester, Ky., Professor C. J. Norwood, who is directing the work of the Kentucky Geological Survey, set forth some important facts about the progress made by the survey since its revival in 1904, what it is now doing and what is still before it. He dwelt particularly upon investigations that have been made into the coal resources, and upon the necessity for further study in that direction. But he also called attention to the possibilities in clays suitable for firebrick, for stoneware and cement manufacture, in lead, zinc and fluorspar and in gas. Those who heard the speech and who have followed the work under Professor Norwood's direction will undoubtedly agree with his suggestion that provision be made for a permanent annual fund for the support of the survey, instead of depending upon biennial legislative

appropriations. Kentucky suffered through the lapse of support of its survey for several years, and it has in the experience of other states that have maintained permanent surveys a practical lesson in the value of such a policy.

THE GEOLOGISTS of the U. S. Survey who have worked in Alaska have all returned from the field of operation. Mr. A. H. Brooks, in charge, returned October 6 from an extended trip along the Yukon River and to Cape Nome, during which he covered about a thousand miles, of which six hundred miles by foot and three hundred miles by canoe.

DURING THE PAST field season Mr. L. M. Prindle examined the newly discovered Kantishna district, about one hundred miles southwest of Fairbanks, on the Tanana. Encouraging reports have lately been received from this placer field, and some gold has been taken out during the last season.

MR. ADOLPH KNOPF and MR. SYDNEY PAIGE examined the coal fields and placers to the north of Cook's Inlet.

THE CHAIR of geology, at Vassar College, vacant by the death of Professor William B. Dwight, has been filled by the appointment of Dr. George B. Shattuck, associate professor at the Johns Hopkins University.

THROUGH THE GENEROSITY of Mrs. Israel C. Russell, widow of the late Professor Israel C. Russell of the University of Michigan, the library belonging to Professor Russell has been donated to the department of geology of the University of Michigan.

PROFESSOR WILLIAM HERBERT HOBBS, formerly professor of the Wisconsin University, has been made professor of geology in the University of Michigan.

MR. T. A. RICKARD, editor of the *Mining and Scientific Press*, attended the meeting of the American Mining Congress in Denver and read an interesting paper on the geological distribution of gold.

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